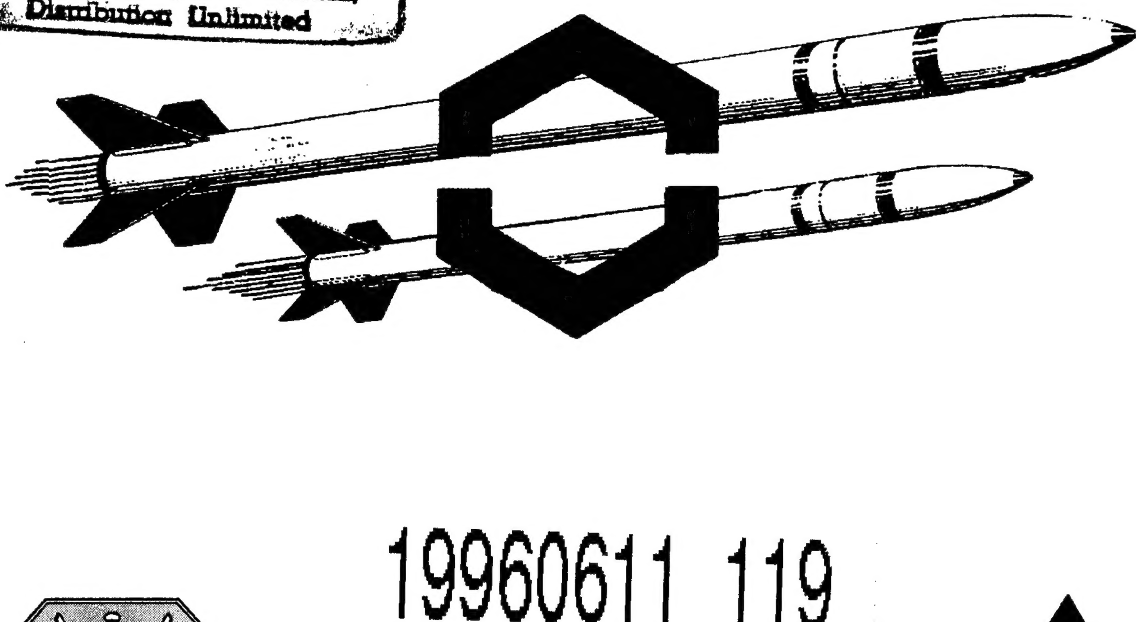
"WE DEVELOP MISSILES, NOT AIR!"

The Legacy of Early Missile, Rocket,
Instrumentation, and Aeromedical Research Development
at Holloman Air Force Base

by
Wayne O. Mattson
and
Martyn D. Tagg

With a Contribution by
George House



Holloman Air Force Base
Cultural Resources Publication No. 2

Title: Quote from a speech by the Commander of Holloman Air Development Center after the base was designated the Air Force Missile Development Center in 1957.

Cover Design: International Space Hall of Fame logo with rocket by Ann LeBlond.

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Air Combat Command
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PREFACE

Martyn D. Tagg
Holloman AFB Archaeologist

The Department of Defense (DoD) is the steward of about 25 million acres of land in the United States and is responsible for the management and protection of a wide variety and large number of irreplaceable natural and cultural resources. Congress elevated the stewardship of these resources by enacting Section 8120 of the Fiscal Year (FY) 1991 Defense Appropriations Act to establish and fund the Legacy Resource Management Program (Public Law 101-511). [1]

The purpose of the Legacy Program (LRMP) is to "promote, manage, research, conserve, and restore the priceless biological, geophysical, and historical resources which exist on public lands, facilities, or property held by the DoD." The functions of LRMP are divided into Program Development tasks for biological, cultural, and geophysical resources. [2] These are further divided into Specific Task Areas for project management, survey of current programs, data management, decision frameworks, earth resources, biological resources, cultural resources, the Cold War, education, public awareness and recreation, Native American and settler communities, and stewardship education and training. [3] Demonstration Projects are currently being conducted at more than 90 DoD installations throughout the country. Legacy partners outside the DoD are participating in the program along with resource specialists at the installation level.

Holloman Air Force Base (HAFB), an Air Combat Command (ACC) base, is one of the installations with LRMP projects. HAFB administers 58,410 acres in southern New Mexico. Prior to FY 93, only $3^1/_2$ percent of this acreage had been inventoried for cultural resources, and four archaeological sites had been documented. Because of the limited nature of the archaeological work and the small size of most surveys, little is known about the cultural resources on base administered properties. The LRMP has become a method to advance this knowledge, providing the means to complete projects not eligible for compliance-driven funds. HAFB became involved in the Legacy Program in FY 93 with the funding of three cultural resource projects. These projects were identified as "milestones and priorities for National Register Surveys" in the draft HAFB Historic Preservation Plan and included a Historic Architectural Assessment, a Thematic Survey of Early Missile, Instrumentation, and Test Object Sites, and a Thematic Survey of Historic Ranches and Ranch Sites. [4] The projects fulfill the FY 93 Legacy Topical Theme of "WW II and Cold War research topics and stewardship projects, and development of other contemporary history themes which contribute to stewardship." [5]

To facilitate the completion of LRMP projects, a Memorandum of Understanding (MOU) was created between HAFB and the New Mexico State Historic Preservation Division (HPD). This cooperative agreement was beneficial to both agencies. It allowed HPD to become more actively involved in the LRMP, and it gave HAFB access to qualified archaeologists, historians, historic architects, and

certified staff. The HPD managed the logistical aspects of the projects and issued grants to organizations or individuals with the experience to provide the best possible final products. The HAFB Archaeologist was the technical manager of the projects, ensuring the results would provide the information necessary for management of resources on HAFB, compliment the base mission, and meet the LRMP guidelines.

The Thematic Survey of Early Missile, Instrumentation, and Test Objects Project (Legacy No. 767) falls under the LRMP Task Area of the Cold War, with the objective to "inventory, protect, and conserve the physical and literary property and relics of the Department of Defense connected with the origins and development of the Cold War."[6] The project was designed as a demonstration project to begin the identification and documentation of known early missile, instrumentation, and test object sites on HAFB administered lands. Six "space-related historical sites" were identified by the International Space Hall of Fame (ISHF) in the HAFB Historic Preservation Plan [7], and five additional facility categories were identified by the HAFB Archaeologist. The physical remains of the facilities were documented as archaeological sites or historic buildings by the HAFB Archaeologist and historic architects from Human Systems Research, respectively. To provide as much documentation as possible on these sites and their role in the development of Cold War technology, the ISHF conducted oral interviews and archival research, which produced a wealth of information including old photographs, films, and military records.

The Early Missile Project was very successful for a number of reasons. Wayne Mattson, the LRMP project coordinator for the ISHF, brought personal experience to the project. During his Air Force career, Mr. Mattson was stationed at HAFB and worked at Able 51, one of the sites investigated during the project. The ISHF also had extensive archives relating to HAFB, and this project provided the opportunity to explore these resources. Abundant microfilm and historic military records were also located at Maxwell Air Force Base (MAFB) and the National Archives. The combination of archaeological documentation, archival research, and oral interviews has provided a more complete picture of an often overlooked cultural period on HAFB -- development of missiles and instrumentation during the beginning of the Cold War.

This report is the second of the HAFB cultural resource publication series, which was created to showcase the wide variety of projects made possible through the LRMP. The publication series will insure quality reporting of LRMP project results and allow data to be distributed to local professionals and other DoD installations, since the results are useful far beyond the boundaries of HAFB. It is hoped this project will encourage other bases to begin the process of documenting and reporting on the many unique Cold War facilities located on DoD installations, thus providing a better understanding of our role during such an important time period in United States history.

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ACKNOWLEDGMENTS

Wayne O. Mattson

Doing the research for this project I read many documents, talked to many people, and recorded what I thought they told me. Any errors in interpretation for what I found are strictly mine and should not reflect upon any sources I have used or people who graciously gave of their time to tell me about the 'good old days.'

This LMRP project was conducted for Holloman Air Force Base through an agreement between the State of New Mexico Historic Preservation Division and The International Space Hall of Fame (Project 35-93HAFB-2). Appreciation is extended to those persons who coordinated this agreement, especially Martyn D. Tagg, the HAFB technical manager for this project. He was always readily available to answer questions, share information, and lead expeditions cross-country into the 'wilds of the New Mexico desert' encompassed by the boundaries of Holloman Air Force Base.

Individuals at numerous organizations helped to uncover archival materials. Among these organizations were the Alamogordo Public Library, the National Archives in Washington, DC, the Air Force Museum at Dayton, Ohio, and the Air Force Historical Research Agency in Montgomery, Alabama.

Administrative and financial support was provided by personnel from the Historic Preservation Division who were forced to suffer through my attempts to understand the State of New Mexico paperwork system. Their instructions were outstanding and I was finally able to successfully operate inside the system.

I would especially like to acknowledge the Space Center personnel involved in this project. Executive Director J. Edson Way and later Executive Director Don J. Starkey encouraged my efforts and pushed me toward bigger and better research. Bob Turner, was able to find every goof that I made through his proof reading ability. He, George House and I spent many hours in the heat of the desert visiting the various sites. Rick Allred, the Space Center photographer, obtained many of the high-class photographs which grace this report. Jack Moore, our knowledgeable editor, was able to put up with my constant use of military terminology and my doing things in military fashion and to convert my efforts to something that made sense to civilian readers. Last, but by no means least, Ann LeBlond was able to use her magic computer to generate the report and incorporate all the photographs at the proper locations.

Special thanks are due to all those who participated in the Oral History Program, gave generously of their time, and furnished, for posterity, a valuable insight into past events.

Marty D. Tagg

The completion of this project would not have been possible without the support and cooperation of a number of people. The cultural resource program at HAFB functions efficiently because of the support of Howard E. Moffitt (Deputy Base Civil Engineer), John R. Poland (Environmental Flight

Chief), and Dr. Paul Green (ACC Headquarters Archaeologist). Others whose support was invaluable include Roger Wilkson and Cathy Giblin (Environmental Flight Chiefs during the time involved), Thomas Merlan and Michael Taylor (New Mexico State Historic Preservation Officer, then and now) and their staff, Dr. J. Edson Way and Don Starkey (ISHF Directors, then and now), and the authors, Wayne Mattson and George House (ISHF Coordinator and Curator, respectively).

Specific to the project, Chris Wende produced the wonderful illustrations which greatly enhance the report. He is a magician with a computer. SRA Scott Mertens took last minute photographs of many of the archaeological features. Dr. Newell Wright, Eglin AFB Archaeologist , provided information on Eglin's JB-2 testing and sites, and kindly allowed the use of one of his photographs. Debbie Hall, Hill AFB Cultural Resource Manager, and the Utah SHPO's office, provided information on the Wendover Army Air Field (now Hill AFB) missile sites and promptly sent a copy of the GAPA National Register Form. H. Michael Gelfand commented on the final draft, catching many errors and inconsistencies previously missed. Lori Hawthorne did the cultural resource editing and formatted the report so it flowed more smoothly. Her professional comments, and general and moral support for the duration of the project, especially during the final weeks, were invaluable.

LIST OF ACRONYMS USED IN THIS REPORT

AAAB	Alamogordo Army Air Base
AAAF	Alamogordo Army Air Field
AAC	Army Air Corps
AAF	Army Air Force
AAFB	Alamogordo Air Force Base
ACC	Air Combat Command
ADN	Alamogordo Daily News
AFB	Air Force Base
AFL	Aeromedical Field Laboratory
AFMDC	Air Force Missile Development Center
AGL	Above Ground Level
APL	Applied Physics Laboratory
ARL	Aeromedical Research Laboratory
ASCE	American Society of Civil Engineers
ASL	Above Sea Level
BOMARC	Boeing-Michigan Aeronautical Research Center
BQM	Controllable Bomb/Ground Launch Missile
BTU	British Thermal Unit
CECNC	49th Civil Engineering, Engineering Flight
CDT	Central Daylight Time
CEP	Circular Error of Probability
CERR	49th Civil Engineering, Real Property Office
CEV	49th Civil Engineering, Environmental Flight
CRM	Cultural Resource Management
CW	Continuous Wave
DoD	Department of Defense
EEG	Electroencephalogram
EKG	Electrocardiogram
F	Fahrenheit
FY	Fiscal Year
FZG	Flak Aiming Device (German)
G	Force of Gravity
G/M	Guided Missile
GAPA	Ground-to-Air Pilotless Aircraft
HABS	Historic American Building Survey

HADC	Holloman Air Development Center
HAER	Historic American Engineering Record
HAFB	Holloman Air Force Base
HAM	Holloman AeroMed
HAR	Holloman Archaeological Resource
HF	High Frequency
HPD	Historic Preservation Division
HTS	Horizontal Test Stand
IM	Interceptor Missile
ISHF	International Space Hall of Fame
JATO	Jet Assisted Take-Off
JB	Jet Bomb
KOH	Potassium Hydroxide
LA	Laboratory of Anthropology
LRMP	Legacy Resource Management Program
MACH	Mach Number - Speed of Sound
MAFB	Maxwell Air Force Base
MOU	Memorandum of Understanding
MSL	Mean Sea Level
MSQ	Unknown
MTSA	Missile Test Stands Area
MX	Missile
NAA	North American Aviation, Inc.
NASA	National Aeronautics and Space Administration
NATIV	North American Test Instrumentation Vehicle
NMCRIS	New Mexico Cultural Resource Information System
NRL	Naval Research Laboratory
RATO	Rocket Assisted Take-Off
RCA	Radio Corporation of America
SCR	Signal Corps Radio
SF	Square Feet
SHPO	State Historic Preservation Officer
SM	Strategic Missile
SMART	Supersonic Military Air Research Track
STS	Space Transport System
TAC	Tactical Air Command (Now Air Combat Command)
TDRSS	Tracking and Data Relay Satellite System

TM	Tactical Missile
USO	United Service Organization
VHF	Very High Frequency
VLA	Very Large Array
VOR	Visual Omni Range
WAC	Without Attitude Control
WSMR	White Sands Missile Range
WSPG	White Sands Proving Ground
XSM	Experimental Strategic Missile
ZEL	ZEro Length

ABSTRACT

This report contains the initial investigation of the history of missile, rocket, instrumentation, and aeromedical research programs conducted at and around Holloman Air Force Base. Research was completed for 11 programs, including six missile and rocket development complexes, a series of instrumentation facilities used to support missile testing, and four programs involved in aeromedical research. Newspapers, magazines, formerly classified military records, and interviews with people involved provided information about the innumerable testing programs carried out in the area. Archaeological investigations were also conducted at the various sites to document and identify those remains still existing today. The results of this research indicates HAFB played a primary role in the early Cold War development of many programs which represented the beginnings of the United States space program.

Recommendations of potential eligibility to the National Register of Historic Places and management considerations for the archaeological sites, suggestions for future studies of the programs, as well as an overall analysis of the project are also included to help other installations considering a project of this type avoid the pitfalls encountered here. The information presented in this report is not all-inclusive. Additional data is constantly being obtained and retained for incorporation into future investigations of the early military days at HAFB.

INTRODUCTION

Holloman AFB is located on the eastern edge of White Sands Missile Range (WSMR) within the Tularosa Basin of south-central New Mexico. These two military installations have played an important part in the United States' effort towards 'Man In Space' and the maintenance of the defense posture of this country. The onset of World War II was responsible for the establishment of the Alamogordo Bombing and Gunnery Range (now HAFB). The early space-related efforts were carried out on the Range after it was integrated with White Sands Proving Grounds (now WSMR) at the end of the war. HAFB officials, cognizant of the base's important role in U.S. aerospace development, are now attempting to preserve a portion of this early history to preclude it from being lost forever.

As part of the Legacy Resource Management Program, HAFB Archaeologist Martyn Tagg suggested a project to study all known missile, rocket, instrumentation, and aeromedical research sites and programs on HAFB. Early in the process, it was determined that not all programs could be satisfactorily covered in the time allotted and with the available resources. As a result of this evaluation, eleven programs were investigated, including six missile and drone development complexes, a series of instrumentation facilities (cinetheodolite stations), and four aeromedical programs. Six of these left physical remains which were investigated using cultural resource methods, resulting in the documentation of two new archaeological sites and updating of four previously recorded sites. These include the Jet Bomb 2, North American Test Instrument Vehicle, Ground-to-Air Pilotless Aircraft, and Aerobee launch complexes (all part of the Missile Test Stands Area [MTSA]), six cinetheodolite stations (two within the MTSA), and Able 51. Most of the structures on these sites have been evaluated as historic structures. [1]

The remaining programs did not leave archaeological remains. One missile development complex, the Horizontal Test Stand (HTS), consists of a facility documented only as a historic structure. [2] The Aeromedical Research Laboratory (ARL) is now part of the Primate Research Laboratory main facility and biocontainment unit. Because of the continued use of these facilities, the historical value of the buildings was not assessed. The Daisy Test Track and projects Manhigh and Excelsior have no physical remains left to document. The Daisy Test Track, once located on the grounds of the ARL, is currently curated in it's entirety at the International Space Hall of Fame. Projects Manhigh and Excelsior used existing runways as balloon launch pads, and these are not considered historically significant. One program initially listed for research was the High Speed Test Track. Since the research base of this facility was so large, it was deemed worthy of an entire project by itself and was not investigated for this project. Future research will enable a thorough evaluation of this program.

Once the various programs were chosen and the physical remains documented, archival research was conducted. This research included microfilm files of the Alamogordo newspaper at the public library and newspaper office, archives at the ISHF, and microfilm obtained from the Air Force Historical Research Agency at Maxwell AFB. In addition, travel to the National Archives and the Air Force Museum was accomplished in an effort to gather and refine data. Oral history interviews already on file

at the ISHF were reviewed and new interviews conducted. The data obtained was correlated between the various sources to ensure accuracy, and further field investigations conducted to determine functions of features on the archaeological sites.

This report represents the culmination of the efforts of collecting and recording the early history of HAFB's role in missile, rocket, instrumentation, and aeromedical research testing and development. It presents a history of the various space-related programs and describes the physical remains still existing on the base. These programs were many and varied, and represented the U.S. military transition from developing and maintaining a technological edge in warfare to reaching for space. Missiles were developed to learn propulsion methods, tests determined if the environment was such that man could exist in space, and other tests were conducted to insure a safe return from space. The data presented here, much of which was from little known, formerly classified projects, provides the foundation for further, more in-depth research into the pioneering studies in modern technology carried out on HAFB. Future investigations will enable a more thorough evaluation of these projects, and others not covered here. The project also provides the first step in the preservation of the unique sites where early testing was conducted, and is the forerunner of many additional projects which will record the efforts and contributions of early experimentation conducted in the deserts of southern New Mexico.

PHYSICAL AND HISTORICAL BACKGROUND

Physical Environment

Project Location

Holloman AFB is located in the Tularosa Basin of south-central New Mexico, approximately 220 miles southwest of Albuquerque (Figure 1). The main base covers 50,999 acres, with an additional 7,411 acres of detached lands at the Boles Wells Water System Annex. The Tularosa Basin is largely administered by Federal agencies, with HAFB bounded on the south, west, and north by White Sands Missile Range, on the south and west by White Sands National Monument, and on the south by the Bureau of Land Management. Private and State lands are to the east.

Tularosa Basin Environment

The Tularosa Basin consists of a closed alluvial landform surrounded on the north, east, and west by high, rugged, fault block mountain ranges. Topography within the basin includes white gypsum sand dunes, lava fields, upland flats, alluvial fans, deep cut draws, and late Pleistocene lake beds. HAFB lies on the lower, relatively flat alluvial plains below the Sacramento Mountain piedmont and is bordered on the west by the White Sands dune field. Elevations range from 4000 to 4200 feet above sea level (ASL). Tularosa Peak, a small volcanic plug, is located at the north end of the base and is a prominent landmark at an elevation of 4398 feet ASL. Water sources consist of several intermittent streams crossing the base from northeast to southwest, and a number of ephemeral springs located along an active fault line. Late Pleitocene lake beds, scattered throughout the basin, collect water during the summer rain storms. [1,2,3]

The climate in the Tularosa Basin is arid, with hot summers and mild winters. The mean annual temperature is about 61 degrees Fahrenheit (F), with 90 degrees F or higher common in the summer months and freezing temperatures not uncommon in the winter. Less than ten inches of rain falls annually, most in the pronounced summer monsoons. Soils are mainly of the Holloman-Yesum gypsum land-Yesum type, which is a sandy loam high in saline and gypsum content. Chihuahuan Desert

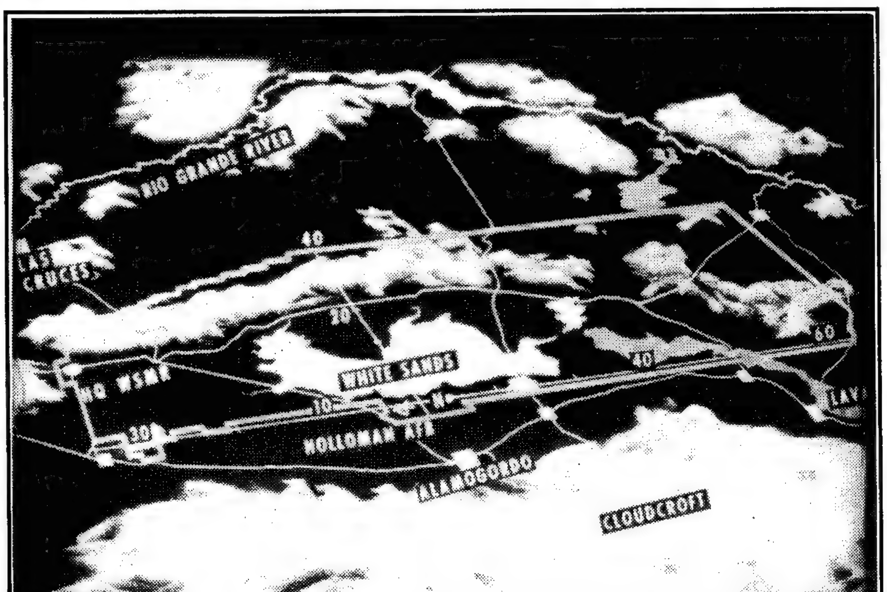


Figure 1. Locations and Relationships in south-central New Mexico (Space Center archives).

scrub is the main vegetative community found throughout the basin, which is dominated by Creosote Bush, Mesquite, Four-wing Saltbush, Rabbitbrush, Tarbush, Crucifixion Thorn, annual grasses, and various cacti. Tamarisk, or salt cedar, is a recent invader and is associated with Cottonwoods near water sources. Fauna consists mainly of small to medium-sized mammals, reptiles, and birds. These include coyote, cottontail, jackrabbit, badger, various rats and mice, snakes, and lizards. [4,5]

Military Potential

The natural and political setting of the Tularosa Basin played a large part in the use of HAFB as a Guided Missile Test Facility. Before coming to HAFB, the U.S. Air Force carried out guided missile research and development testing in various places throughout the United States, including western Florida, southern California, southern Nevada, and south-central Utah. These programs were abandoned for a number of reasons. When the Alamogordo/White Sands area became available in 1946, Air Material Command took the steps to move the program there because "it is the only area suitable for the purpose . . . within the borders of the United States. The nature of guided missile testing demands an area that is large and relatively free of habitation . . . and remote from large areas of population. It must be fairly level because of the necessity for extensive range instrumentation and missile recovery. The weather must be such as to facilitate year-round operation, and the visibility must be exceptional." [6]

Historical Background

Space Technology In New Mexico (by George House)

Interest in space technology in the deserts of New Mexico began long before the military testing of the 1940s. Early man, interested in the mysteries of space, studied the skies above New Mexico hundreds of years ago. The stars and the sun played an important role in his daily life and prehistoric observatories dot the Land of Enchantment's landscape. Modern man, also striving to understand more about the universe, has built some of the world's most sophisticated observatories in New Mexico, and more are planned for future use.

Several potential prehistoric solar observatories are located in the Sacramento Mountains to the northeast of HAFB. One of these is Walley's Dome (named after its discoverer, Walley Hesse). Featured at this early site are several upright rock formations supporting a horizontal rock slab, which seems to be astronomically aligned to record annual solstice events. [7]

Modern celestial observatories in New Mexico allow today's sky-watchers to observe and probe the universe on a much grander scale. For example, the National Radio Astronomy Observatory near Socorro (northwest of HAFB) boasts the Very Large Array (VLA), which consists of 27 giant dish-shaped antennas (plus one spare) linked to form what is currently one of the world's largest radio telescopes. Each antenna collects incoming cosmic radio signals and sends them to a central location, where astronomers combine these signals to make detailed pictures of extremely faint objects in space.

By studying radio waves, scientists can gain new kinds of knowledge on the origins, physical characteristics, and history of celestial objects.[8]

The National Solar Observatory is located at Sunspot, New Mexico, and is visible from HAFB. Operated by the Association of Universities for Research in Astronomy, Inc., Sacramento Peak, as it is also called, is a national center for ground-based observations of the sun, with major funding provided by the National Science Foundation. Scientists from around the world visit Sacramento Peak to pursue solar research programs.[9]

But man's quest for understanding has not been limited to earthbound observations. Man needed to reach higher to observe space and its surroundings in order to some day physically travel to this frontier. Robert Goddard's early rocket tests in New Mexico set the tone for later rocket research at HAFB and WSMR. Those early steps at the base and the missile range were among the first taken towards the United States' present-day space program (see Appendix 1 for timeline).

Robert H. Goddard, regarded as the father of modern rocketry, launched the world's first liquid-fueled rocket on 16 March 1926. The launch site was a cabbage patch on a farm near Auburn, Massachusetts. His rockets soon attracted the attention of the State Fire Marshal, who asked Dr. Goddard to take his experiments elsewhere. Goddard sought an area with clear skies, sparse population, level ground, and minimum precipitation. He chose a site near Roswell, New Mexico, to continue his research. From 1930 to 1932, and from 1934 until 1941, Dr. Goddard and his staff pioneered many of the techniques used in today's rockets.[10]

When the United States Army decided to embark on guided missile programs, they found they needed a test range. Like Dr. Goddard, they required an area with large expanses of uninhabited terrain, extensive level regions, and predominantly clear skies, to permit year-round operation. The Tularosa Basin in southern New Mexico met most of their missile range requirements.[11]

At the time of the Army's decision to use the Tularosa Basin for missile testing, a range was already in existence. Alamogordo Army Air Field (AAAF) had been in operation since 6 February 1942, and possessed an extensive bombing and gunnery range.[12] Later the Army Range (which became WSMR) and the Alamogordo Bombing and Gunnery Range (which became the HAFB Bombing and Gunnery Range) were combined on 1 September 1952.[13]

The tests conducted at HAFB, first the Bombing and Gunnery Range and later the integrated HAFB/WSMR, included ground-launched missiles, air-launched missiles, rocket sleds, balloons, parachutes, biomedical experiments, and even automobile crash tests. These tests were part of the early history of the United States Air Force space program and reflected the ever-constant quest of mankind to obtain the knowledge needed to reach outer space. HAFB took the first steps in this direction.

Holloman Air Force Base

Holloman Air Force Base, New Mexico: today, the name brings to mind the image of a black, bat-like airplane known as the F-117A Nighthawk, or Stealth Fighter. Five years ago, it might have pro-

duced the vision of an F-15 Eagle or an F-4 Phantom II. During the Cold War, the image would have been that of various test aircraft, missiles and drones, or sleds roaring down a 'set of railroad tracks' in the middle of the desert.

The concept of HAFB was initiated on Easter Sunday, 13 April 1941, during a meeting between Major General Henry H. Arnold, Chief of the Army Air Corps, and Vice Marshal Sir Guy Garrod, Royal Air Force Chief of Training. This meeting led to the establishment of the British Training Program, which initiated construction of what is today known as HAFB. Because the base was for the British to train their bomber crews, the three-area arrangement of the base cantonment (i.e. the main base, west, and north areas) reflects the typical Royal Air Force base design. [14]

In October 1941, New Mexico ranchers on lands designated for the establishment of the bombing range near Alamogordo were ordered by the government to dispose of their livestock in anticipation of evacuating the area. As would be expected, the Board of County Commissioners of Otero County protested to the War Department, but the protests were of no avail. On 19 November 1941, a group of officials from Headquarters, Fourth Air Force, located at Riverside, California, visited the area to inspect the site of the proposed military installation. The following month local stockmen were notified that leases to public lands used for grazing were cancelled and stock would have to be removed. Due to the entry of the United States into World War II, protests over this order were limited. Finally, on 6 February 1942, construction was started on the AAAF.

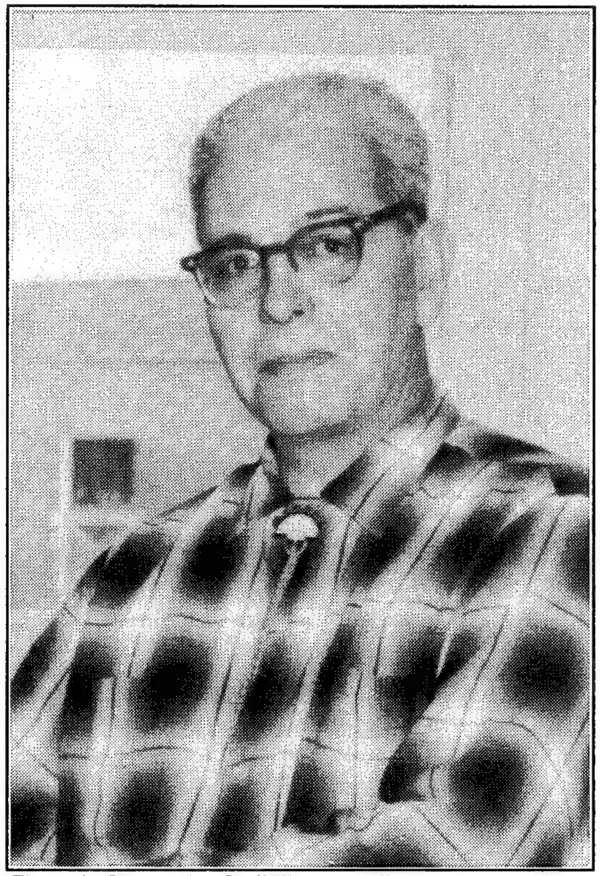


Figure 2. Christopher L. Gallegos ca. February 1967 (Photo courtesy of the family of Chris Gallegos).

The first act of work was cutting a strand of barbed wire on one of the fences surrounding the grazing land where the base was to be built. The man who 'started it all' was Christopher L. Gallegos, who cut the first strand of barbed wire at a point about one-half mile west of where the main gate now stands (Figure 2). Later, Mr. Gallegos worked on HAFB for Air Installations (which evolved into Civil Engineering) as a planner and was responsible for siting many of the permanent buildings. [15]

Military personnel first arrived at AAAF on 10 April 1942 when a lieutenant and 30 enlisted men were transferred from Davis-Monthan Field in Arizona. Some barracks were ready for use but there was no electricity, and water had to be hauled in by trucks. [16] The following month, 5 May 1942, the 359th Headquarters Squadron arrived at AAAF. This was the first organization to be assigned to the

new installation. Two days later Army Air Force officials visited Alamogordo to survey the housing situation in preparation for the expected influx of civil service employees who were to assist in the operation of the base. Sixty civil service employees were expected to arrive by 1 June 1942. The citizens of Alamogordo joined the United Service Organization (USO) drive and requested a local USO unit to serve military personnel from the new nearby base.[17] Finally, on 27 May 1942, the 301st Bombardment Group arrived as AAAF's first tactical unit.[18] The following month, B-17s arrived and training was started at the air field. Later during the war, the B-17s and B-24s were replaced with B-29s (Table 1).[19]

On 16 July 1945, a momentous event took place, not on AAAF itself but in the northwest corner of the Alamogordo Bombing and Gunnery Range. The first atomic bomb was detonated at Trinity site, which is currently administered by WSMR.[20] This detonation proved to have an earthshaking effect on the world, and the results influenced much of the testing that later took place at HAFB.

After the end of World War II, the military was rapidly and severely reduced and on 28 February 1946, an announcement was made that AAAF would be inactivated.[21] The B-29s left Alamogordo the following month as activities at the air field wound down. One week after the B-29s left, the base inactivation was halted, and on 10 April 1946, AAAF was reactivated and assigned a missile development role.[22] The newly reactivated base was at first under operational control of the Fifteenth Air Force and then, in November 1946, under control of the Eighth Air Force. On 26 February 1947, jurisdiction of AAAF was transferred to the Air Material Command and guided missile programs began their move to New Mexico with a scheduled completion date of September 1947.[23] When the base was reactivated again in 1947, it had a missile range that was 64 miles long, running north and south, and 38 miles wide. This range was felt to be superior to the facilities at Wendover Army Air Field in Utah. At the same time, the Army Ordnance Corps built White Sands Proving Ground (WSPG), which had its range just to the south of the HAFB range. These two installations worked together informally in order to schedule for the maximum efficient use of the combined range, which was 100 miles long and 40 miles wide.[24]

It appeared that the transfer from Utah and closing of Wendover AAF met with few problems because on 23 July 1947, the first firing took place at AAAF. A Boeing Ground-to-Air Pilotless Aircraft (GAPA) was successfully launched at 8:00 a.m. The GAPA was a 20-foot-long missile and was launched with three Jet Assisted Take-Off (JATO) motors to furnish the initial boost after which the GAPA motor was ignited.[25] The GAPA never became a finished weapon but evolved into the IM-99, known as the BOMARC (Boeing-Michigan Aeronautical Research Center) missile.[26]

In September 1947, the Air Force became a separate service, and AAAF was renamed Alamogordo Air Force Base (AAFB) for a short time. General Order No. 2, issued 13 January 1948 by Headquarters, U.S. Air Force, designated AAFB as Holloman Air Force Base (Table 2). Colonel George V. Holloman was an early pioneer in guided missiles who was fatally injured in a B-17 crash in March 1946, so it was quite appropriate that a guided missile development base would be named in his honor.[27] The official dedication ceremonies marking the renaming of the base took place on 18 September 1948.

Table 1
Wartime Units At Alamogordo AAF

Organization	Aircraft	Dates Assigned
301st Bombardment Group	B-17	27 May 1942 - 21 June 1942
303rd Bombardment Group	B-17	17 June 1942 - 7 August 1942
330th Bombardment Group	B-24	1 August 1942 - 5 April 1943
392nd Bombardment Group	B-24	18 April 1943 - 18 July 1943
454th Bombardment Group	B-24	1 June 1943 - 1July 1943
455th Bombardment Group	B-24	1 June 1943 - 6 September 1943
459th Bombardment Group	B-24	1 July 1943 - 31 August 1943
460th Bombardment Group	B-24	1 July 1943 - 31 August 1943
449th Bombardment Group	B-24	5 July 1943 - 12 September 1943
450th Bombardment Group	B-24	8 July 1943 - 20 November 1943
465th Bombardment Group	B-24	1 August 1943 - 1 September 1943
466th Bombardment Group	B-24	1 August 1943 - 31 August 1943
36th Fighter Group	P-47	1 September 1943 - 30 September 1943
400th Bombardment Group	B-24	19 September 1943 - 15 December 1943
492nd Bombardment Group	B-24	1 October 1943 - 1 April 1944
466th Bombardment Group	B-24	24 November 1943 - 5 February 1944
487th Bombardment Group	B-24	15 December 1943 - 13 March 1944
418th Bombardment Group	None	11 March 1944 - 1 April 1944
25th Bombardment Group	B-17	6 April 1944 - 20 June 1944
467th Bombardment Group	B-29	25 August 1945 - 8 September 1945

Source: Air Force Combat Units of World War II, Maurer Maurer, Editor

Table 2
Air Force Genealogy

Army Signal Corps, Aeronautical Division, established 1 August 1907.
First airplane contract, 10 February 1908.
First airplane delivered, 2 August 1909.
Air Service (American Expeditionary Force) established 3 September 1917.
Army Air Service established 20 May 1918.
Army Air Corps established 2 July 1926.
Army Air Force established 20 June 1941.
U.S. Air Force established 18 September 1947.

On 1 September 1952, the operation of the combined HAFB Range and the WSPG Range was formally integrated into the 'Integrated White Sands Range' and placed under Army management.[28] The ranges were combined because many of the missile development programs on the two ranges overlapped.

The importance of HAFB was recognized when, on 10 October 1952, the base was raised to Center status and became Holloman Air Development Center (HADC).[29] Five years later it was designated as the Air Force Missile Development Center (AFMDC) with the following comment by the commander: **"We develop missiles, not air."**[30]

During the period when HAFB was heavily involved in missile development and testing, such terms as Snark, Matador, Mace, Falcon, Aerobee, JB-2 Loon, Firebee, and numerous others were household words. There were also projects involving balloons, high speed sled tests, and Aeromedical Field Laboratory experiments during which Colonel John P. Stapp became known as the 'Fastest Man Alive' and Captain Eli J. Breeding, Jr. sustained a force of 83 G.[31] The Central Inertial Guidance Test Facility and the Radar Target Scatter Test Facility were developed. There was also the Primate Research Facility, which trained HAM (original name Chang), the first chimpanzee to make a suborbital flight and Enos, the first chimpanzee to orbit the earth.[32]

Missile testing and development dropped off but did not cease when the AFMDC was phased out in 1970. On 1 January 1971, Tactical Air Command (TAC) assumed operational control of HAFB which became primarily a fighter base.[33] Developmental testing continued, but many of the old facilities and buildings associated with this effort had been deactivated, allowed to go to ruin, and in general were forgotten. Efforts are now underway to resurrect history and recover what was almost lost.

Target Alamogordo

Although missile testing did not begin at AAAF until July 1947, the population of Alamogordo got its first experience with a missile three months prior to that time. At 4:08 p.m. on 15 May 1947, V-2 No. 26 was launched from Launch Complex 33 at WSMR main base. According to the firing summary table published by the missile range, the empty weight of this vehicle was 9,827 pounds, the burn time for the liquid-fuel engine was 63.6 seconds, the maximum velocity attained by the rocket was 4,696 feet per second (almost 3,202 miles per hour), and, the missile gained an altitude of 76 miles. Although the missile was programmed to pitch over to an angle of seven degrees, it actually pitched over 9.6 degrees. The comment on the firing report stated that "steering was a trouble from lift-off."[34] As the V-2 neared Alamogordo, it began tumbling end over end through the atmosphere. The pressure broke the missile apart, and as wreckage parts screamed to earth, the V-2 succeeded in getting the attention of the residents of the community.

Taking the impact coordinates given in the firing summary, the missile debris landed 35 miles north and 31 miles east of Launch Complex 33. This was the farthest east that any V-2 missile traveled during the vehicle's testing program at WSMR. The Alamogordo News (now Alamogordo Daily News)

reported the missile impacted two-and-one-half miles northeast of town in the "vicinity of Indian Wells." The article further stated that a portion of the wreckage landed on First Street and was gathered up and guarded by local citizens until the Army arrived on the scene to take charge of the pieces. [35]

First Street was not the only area of Alamogordo hit by wreckage from the missile. Parts of the wayward V-2 landed close to the Southern Pacific Railroad tracks, near the intersection of 13th Street and Cuba Avenue, and on Indian Wells Road (Figure 3). The impact point of the largest part of the wreckage was due east of the present site of the ISHF building. Fortunately for the residents of Alamogordo the missile was carrying a payload for the Naval Research Laboratory instead of one of the warheads with which the deadly German missiles were equipped during World War II.

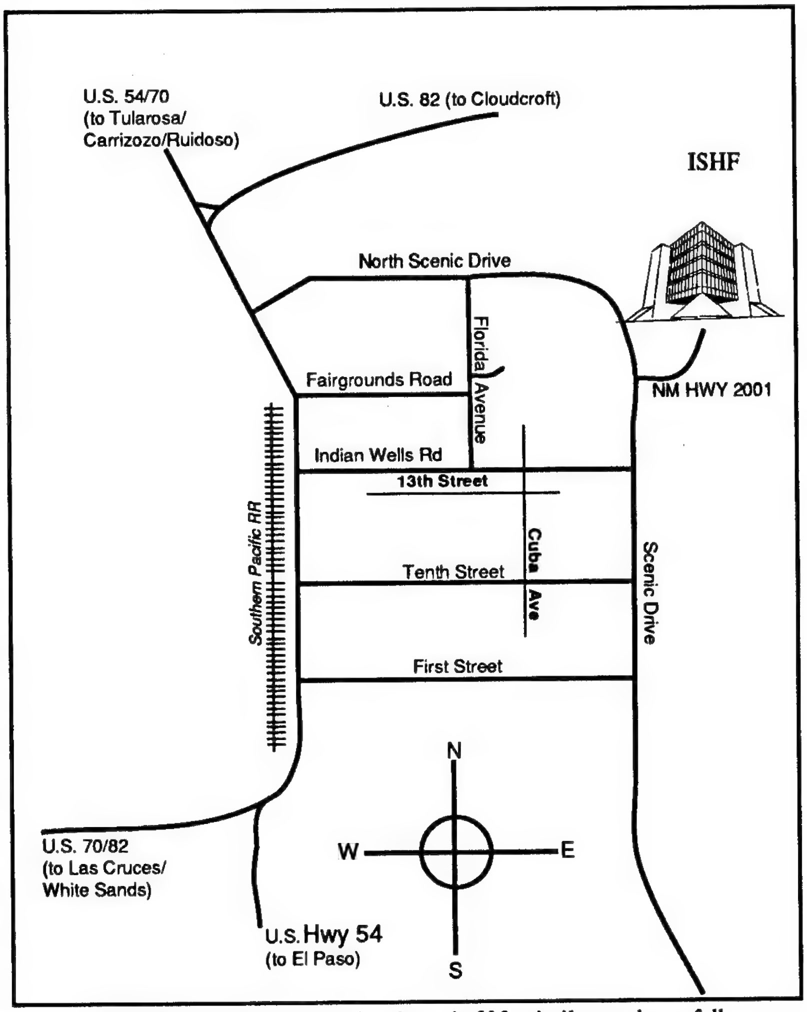


Figure 3. Vicinity map of Alamogordo where the V-2 missile wreckage fell.

Apparently this mishap caused some concern among local citizenry. A June 1947 edition of the Alamogordo News carried an article and a photograph expressing that concern. The photograph was of a V-2 missile the Army brought to Alamogordo to show the local citizens what nearly hit them. The article was about New Mexico Senator Orrin Hatch's request that V-2 tests be halted due to the 15 May incident. However, the Alamogordo Chamber of Commerce contacted Senator Hatch and requested that the testing not be stopped; one member of the Chamber of Commerce commented, "Who's Afraid?" [36]

RESEARCH QUESTIONS AND METHODOLOGY

Research Questions

Holloman Air Force Base, specifically those areas north of the main runway complex, is dotted with slabs of concrete, blockhouses, abandoned structures, and many other items with unknown functions. Some of these can be identified by name and function, while the purpose of others can not be readily determined. Some of the facilities are still in use for test purposes. What were these early structures? How did they fit into the scheme of early missile and Cold War testing conducted at HAFB? What types of programs were conducted, which are still ongoing, and which did not leave physical remains? These were the research questions that were posed.

This project was conducted because the DoD determined that, because of the military base realignment program with resultant closure of installations, construction at others, and changes in missions, early history was being irretrievably lost. Such important data needed to be added to the annuals of Air Force history before the information could no longer be retrieved. The LRMP was developed to collect such information.

The preliminary list furnished by the HAFB Archaeologist had the following research areas:

JB-2 Loon Launch Site
Aerobee Rocket Launch Site
Aeromedical Field Laboratory
High Speed Test Track
Primate Research Laboratory
NATIV Launch Site
Daisy Test Track
Missile Theodolite Towers
Manhigh Project
Horizontal Test Stand
Able 51.

An initial investigation of the areas on the list determined some of the programs actually blended together and could be readily combined in the report. For example, the Aeromedical Field Laboratory (AFL) was the prime agency behind the Manhigh Project and the Daisy Test Track and managed the Holloman Zoo. At the same time, it was discovered that some of the launch sites were used for more than one program, while others were developed solely for a single program. The history of the High Speed Test Track was considered too voluminous to be included in this report because of the variety of tests conducted there and the limited time available for this research project. In order to do justice to this facility, it should be the sole subject of a future historical report.

After determining these facts, a number of questions were posed which directed the preliminary

investigation of each program:

1. What program(s) were involved with a particular archaeological site or features within the site?
2. What was the site like when the program was being conducted?
3. Who, and what (organization), was involved in the program?
4. What tests were accomplished and what were the results of the tests?
5. What remains of the test sites today?
6. What programs were conducted on the base which are not associated with archaeological/historical remains?

Methodology

In order to answer these questions, it was necessary first to determine what was going on at HAFB. A variety of sources were utilized for this purpose. The Alamogordo Public Library contains a complete set of microfilm files from the Alamogordo newspaper, which yielded much preliminary information but did not contain a great amount of detail. Because early programs were classified, such details were not, at that time, releasable to the general public. Military security regulations in effect during the early days of testing at HAFB required the label: "downgrade at 3-year intervals, declassify after 12 years." Such labels were found on all previously classified documents, indicating the early records would now be unclassified and available for public viewing. The storage locations were determined to be at the National Archives in Washington, DC, and the Air Force Historical Research Agency at Maxwell AFB (MAFB), Alabama.

The primary author, from his personal experience in military testing, was aware that each test program was required to submit periodic test reports and a final test report. Therefore, a request was forwarded to MAFB for information contained in their files. A computer printout was furnished after first giving MAFB personnel a list of selected key words such as HAFB, Aeromedical Field Laboratory, JB-2, and Missile Testing. From the computer printout, a series of microfilm records were obtained. These records, many of them formerly classified, yielded information which aided in determining the programs conducted, the types of test vehicles, and the results of the tests.

Information obtained from the National Archives varied from unclassified items to formerly classified secrets. This source was valuable in determining types of tests and programs and for providing information on the sites. In addition, there was information in these files outlining some of the early history of HAFB.

The ISHF has extensive archives containing early unclassified test reports, photographs, news releases and clippings, and information released by contractors. Their library, devoted to the subject of rockets, space, and similar subjects, also proved to be an excellent source for obtaining research data.

The Alamogordo Public Library and the library at the New Mexico State University-Alamogordo

held collections of books that furnished information on the performance and characteristics of various missiles and rockets. The Air Force Museum also maintains a comprehensive library of books, some of which were helpful in finding descriptions and characteristics of the early missiles. Unfortunately, their historical files about HAFB and the test programs conducted there were limited. In addition, the New Mexico State University in Las Cruces had excellent historical files, but these files focused more on the social and cultural aspects of HAFB's history rather than the technical end.

Primary source information was obtained through the medium of oral history interviews with individuals associated with the early testing at HAFB and WSMR. Many contacts were established by placing an article in the Alamogordo Daily News concerning the LRMP and the desire of the ISHF to obtain information and artifacts to support the project. Several individuals came forward to donate photographs and participate in the oral history project. The information obtained was incorporated into the research report, and the photographs were used to determine the early function of some of the concrete pads that still exist at HAFB. In some cases, the data proved to be key in resolving several site problems that were encountered during the course of the research. Unfortunately, many willing candidates could not be interviewed because time or circumstances precluded such actions.

Contractors who conducted testing at HAFB in its early years also were contacted for information. While they maintained good files of photographs, they did not keep complete historical files on the tests they conducted. They did, however, maintain files that aided in determining the characteristics of the various test objects.

Motion picture film, still photographs, and video tapes from all of the above sources were reviewed for pertinent data. While these are viable sources, it was necessary to review motion pictures and video tapes several times in order to properly obtain the desired data. In addition, while they revealed what the test sites looked like during the time frame of the testing, the translation of the photographic image from motion picture to still picture turned out to be less than desired. In several instances, what were considered outstanding views of 'what it looked like back then' had to be scrapped because the images could not be converted to still photographic medium and retain enough clarity to achieve the desired result. Thirty-five millimeter color slides, on the other hand, were converted to still photographs with little or no loss of clarity.

The primary author also made several visits to the sites of the early testing programs to make precise determination of orientation and terrain and to photograph the remains to ensure the original identification of features was correct. Following the receipt of new information from other sources, sites were often revisited to verify the accuracy of this information.

To provide the archaeological perspective of the various programs, the HAFB Archaeologist (also the secondary author) visited the sites and inspected existing cultural resource records to assess the significance of the facilities. The significance of the sites and their association with early missile and rocket testing on HAFB had been recognized prior to the beginning of this project, and initial documentation had been completed on four of the sites between 1992 and 1994.

The physical remains of the facilities were evaluated for placement into two categories: archaeological sites or historic structures. Archaeological sites generally consisted of foundations and scattered artifacts. If buildings remained intact, they were assessed as historic structures. In many cases, a particular facility fell into both categories, while in other cases, no physical remains existed.

The archaeological sites are discussed here. If the facility consisted only of a historic building, it was documented as part of a Historic Architectural Assessment using the Historic American Buildings Survey and Historic American Engineering Record (HABS/HAER) format. These results are discussed in detail in a separate Historic Architecture report.[1] The buildings on archaeological sites will only be discussed briefly in this report.

If a facility was considered an archaeological site, it was documented using the current New Mexico Cultural Resource Information System (NMCRIS) data form. This consisted of a Laboratory of Anthropology (LA) site form with associated site map and photographs. Each site was issued a Holloman Archaeological Resource (HAR) and LA site number. Many sites had been previously recorded. These site forms were updated with the information collected during this project. Site forms are on file at the HAFB Environmental Flight (49th CES/CEV) office and the Laboratory of Anthropology in Santa Fe, New Mexico.

The archaeological sites were documented using standard field methods, including pace and compass maps with metric measurements. The field maps were reproduced for use in the report, with an English scale added below the metric scale. Because original engineering blueprints and military documentation used English measurements, all sites were revisited and features re-measured for consistency in reporting.

References used to identify and date facilities, buildings, and features included the HAFB Real Property Accountable records available for all existing buildings on the base. These are housed in the Real Property office (49th CES/CERR). Original facility and building blueprints, engineering drawings, and maps are available in the HAFB Civil Engineering, Engineering Flight (49th CES/CECNC) drawing vault.

Once the research was completed and the archaeological remains documented, the sites and programs were divided into the three major categories of research which were the focus of this study: missile and rocket complexes and programs, instrumentation facilities, and aeromedical research programs. The missile and rocket facilities included those sites directly involved in development of this early technology. These consist of the GAPA, NATIV, JB-2, Aerobee, and Able 51 launch complexes and the Horizontal Test Stand. The instrumentation facilities include the cinetheodolite sites. Aeromedical Research consisted of the Aeromedical Research Laboratory, Daisy Track, Project Excelsior, and Project Manhigh.

MISSILE and ROCKET COMPLEXES

Six missile and rocket complexes were investigated and are discussed here in chronological order. These include the GAPA, NATIV, JB-2, Aerobee, and Able 51 facilities, and the Horizontal Test Stand. The physical remains of the first five complexes are located within two archaeological sites, the Missile Test Stands Area (HAR-041/LA 104274) and Able 51 (HAR-018r/LA 107799) (Figure 4). Both sites appear to represent focal points for numerous programs carried out on HAFB, with at least four individual launch complexes on the MTSA and three on Able 51. The HTS is included in this section because it was initially used to test rocket engines. The facility has been identified as an historic building.

The MTSA was documented in 1994 as part of a 325-acre survey designed specifically to locate features and map the site. [1] The site is situated on a flat alluvial plain overlooking Lost River, at an elevation of 4,080 feet ASL. Over 150 individual features were recorded as part of this site, which was delineated within a 4,420' x 3,120' area. The features extended to the boundary of the survey area in many places, and it seems apparent from more recent inventories adjacent to this one that the current site boundary will be expanded in the future. In order to ensure accuracy in feature location, the site was mapped using a plane table and alidade. Because the MTSA was used for a variety of different test programs, the association of many of these features with specific test programs has not been assessed at this time, although it can be determined with some certainty that most are associated. For this reason, the archaeological discussion of this site focuses only on those features near the four identified missile testing complexes, GAPA, NATIV, JB-2, and Aerobee.

Ground-to-Air Pilotless Aircraft (GAPA)

The GAPA complex is located within the MTSA just east of the Tula Peak Road on the edge of Lost River (see Figure 4).

Historical Background

In June 1945, the Boeing Aircraft Company started work on the Army Air Force's Ground-to-Air Pilotless Aircraft (GAPA) and a ramjet engine associated with later models of the remote-controlled aircraft. The GAPA, an experimental, high velocity test vehicle, was officially known as MX-606 and led to the development of the operational BOMARC missile. [2] Program MX-606 saw a total of 112 GAPA launches made between 1946 and program termination in 1949. [3] Seventy-two of those launches were conducted at HAFB between July 1947 and August 1950. [4] Even though the Air Force decided to terminate the program in 1949, two additional missiles were launched. The last of these launches, number 114, was conducted on 15 August 1950. [5]

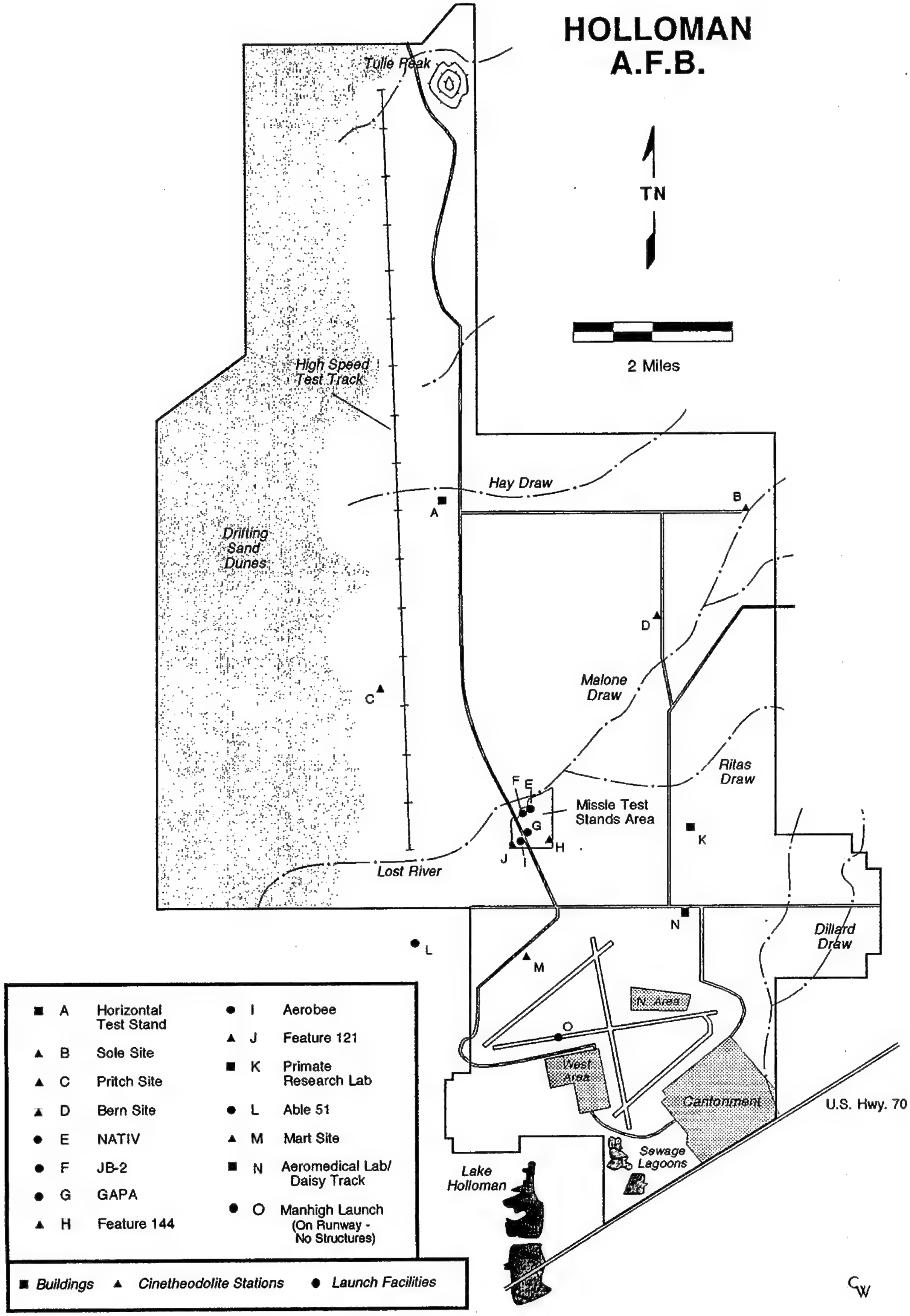


Figure 4. Holloman AFB missile, rocket, instrumentation and aeromedical facility locations.

There were three different series of missiles involved in this test program. The 600 series was a solid fuel rocket, the 601 series was a liquid propulsion rocket, and the 602 series was a ramjet powered missile (Figure 5). All used rocket boosters to become airborne. [6] The first flight test vehicles were propelled by standard Aerojet rocket units. Later models included a booster to accelerate the GAPA to supersonic speeds. [7] GAPA missiles ranged up to 16 feet in length, weighed about 5,000 pounds, and reached speeds of 1,500 mph. They had a high probability of kill up to 80,000 feet. [8] The missile was launched using combinations of three, four, or five rocket boosters. [9,10] After launch, the boosters would fall away and the GAPA would continue using its own engine. The first ramjet powered missile was launched on 14 November 1947, and the first liquid-fuel missile was launched on 12 March 1948. [11] Tracking was accomplished using radar and optics.

The flight test phase of the GAPA program was first conducted at Wendover Field, Utah. However, the AAF decided in 1947 to consolidate all missile and rocket experiments at one location and the GAPA program was moved to AAAF. [12] Boeing Aircraft Company transferred its operation from Utah to Alamogordo and, on 23 July 1947, launched a GAPA from what is now HAFB, New Mexico. That GAPA launch was the first missile firing from AAAF, and was the 39th firing in the test program. [13] Even though operations had commenced at AAAF and were winding down at Wendover, launch number 40 was scheduled at Wendover the day following the AAAF launch. Operations at Wendover ceased 1 August 1947. [14]

On 15 November 1949 a GAPA attained an altitude of 59,000 feet, marking the highest flight altitude for supersonic ramjet propulsion achieved up to that time. Although GAPA never entered production, the design and test experience provided the foundation for the later Boeing-U.S. Air Force IM-99 BOMARC missile program. [15] This interceptor missile became fully operational and was deployed at various Air Force Bases in the United States.

Archaeological Perspective

The remains of the GAPA launch complex consist of three intact structures, a firing apron, a possible magazine, and a number of noncontagious features in a 900' by 600' area (Figure 6). A May 1947 General Plan for the GAPA Test Launching Site shows an observation shelter, firing apron, and an unlabeled feature connected by a cable trench. [16] The observation shelter, designated 'Baker 2' (Building 1139/Feature 94), is a steel-reinforced cast concrete, two-room rectangular structure (Figure 7). The main structure is 20' square (observation room) with an 13' x 20' offset (equipment room) and 660 square feet (SF) of interior space. The building was completed in 1951. [17]

The main observation room has a high hipped roof and 2' thick walls. A steel-framed observation deck is situated along the entire roof ridge and a single hung steel door opens to the south under a breezeway with a sloped shed roof. A 6' wide concrete pad runs along the front of the building. Four inset, trapezoidal-shaped observation windows with 3" thick glass face north towards the firing apron. [18,19,20] There are bullet holes in the glass. A 1' x 6" square concrete box is attached to the east wall.

The equipment room is attached to the west wall of the observation room. It has 8" thick walls, a low

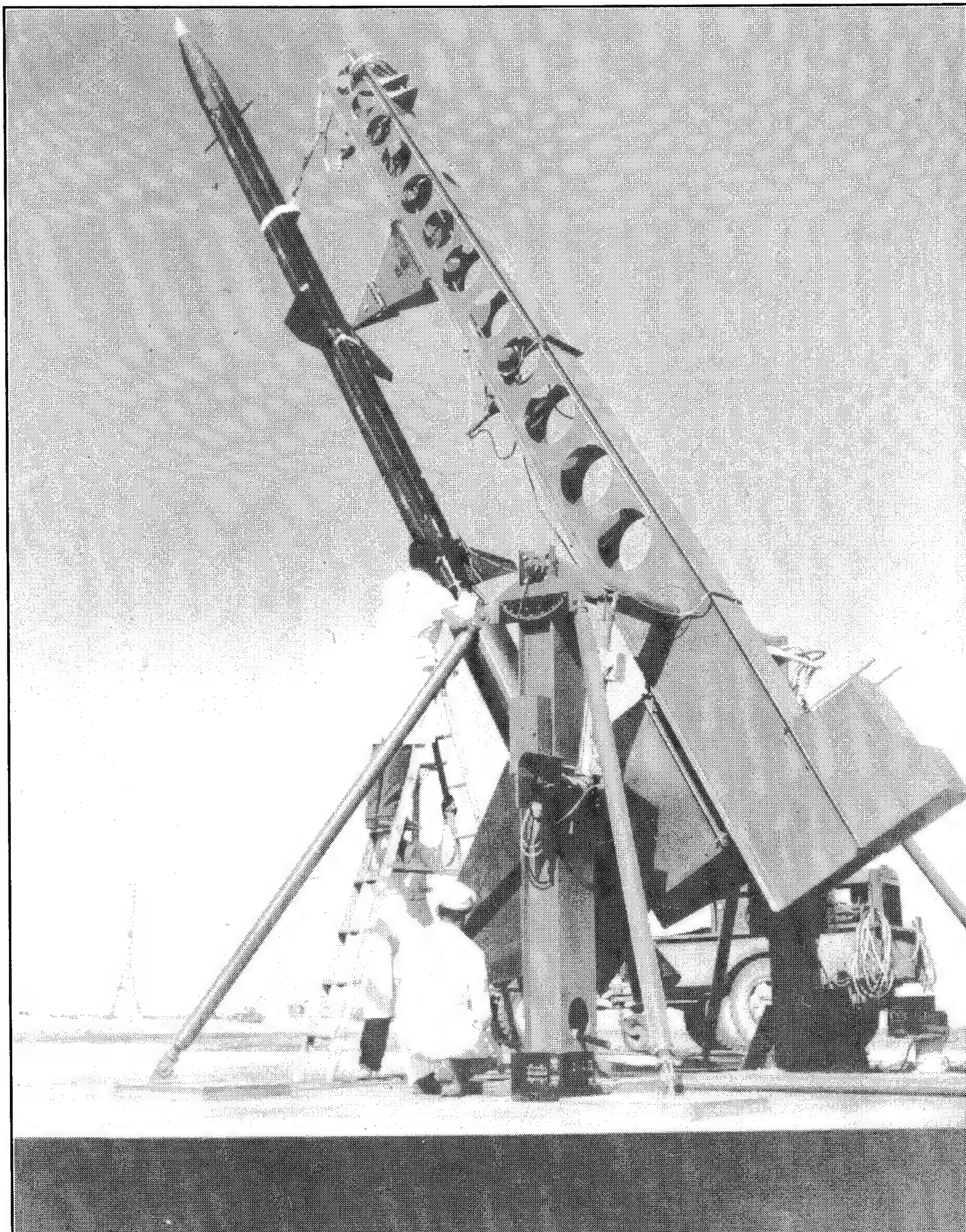


Figure 5. GAPA Model 601 being prepared for launch at the MTSA on HAFB ca. 1948, with JB-2 and NATIV launch complexes in the background (Photo courtesy of The Boeing Company).

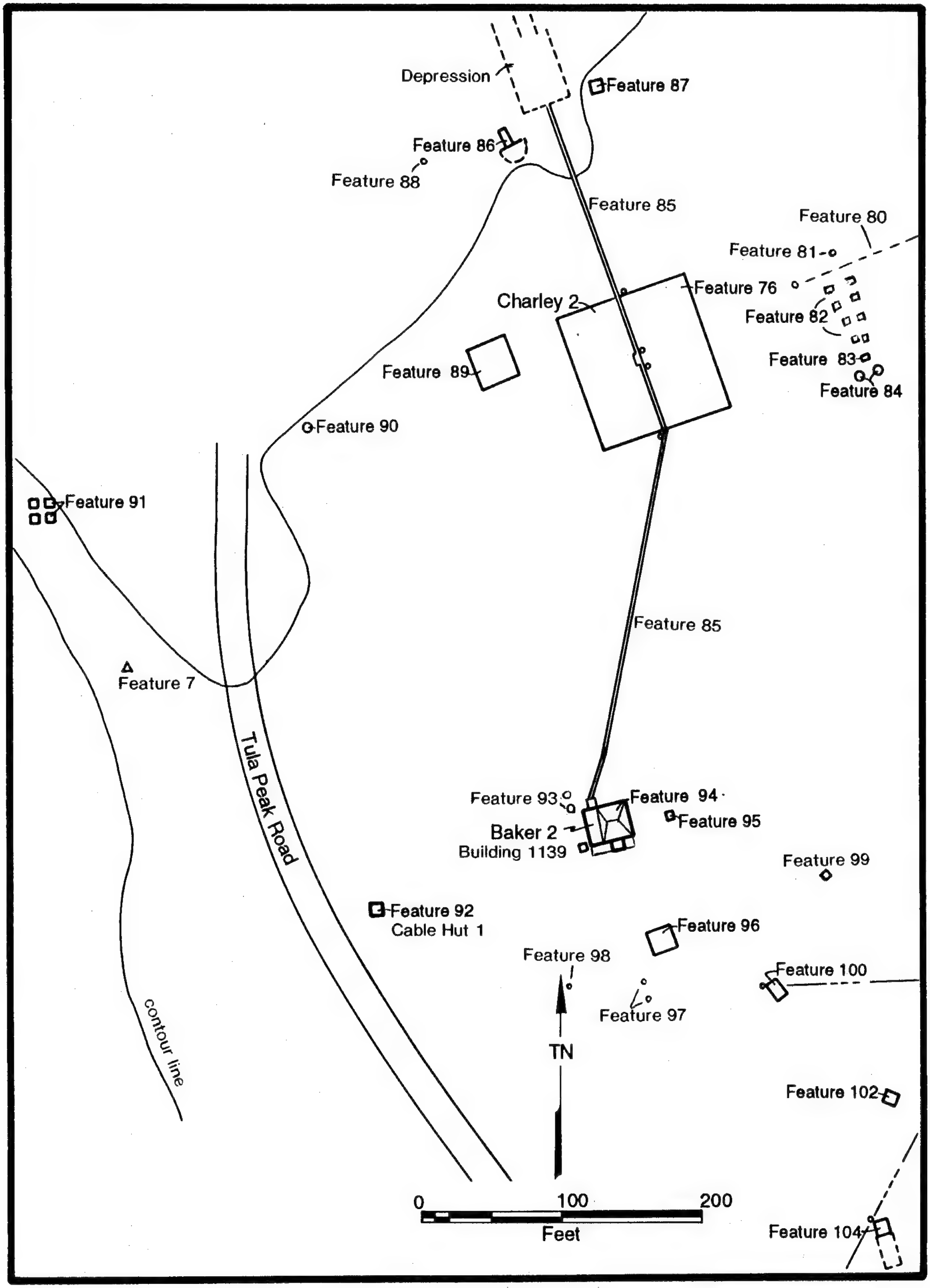


Figure 6. GAPA launch complex map (adapted from Eidenbach and Wessel 1995).

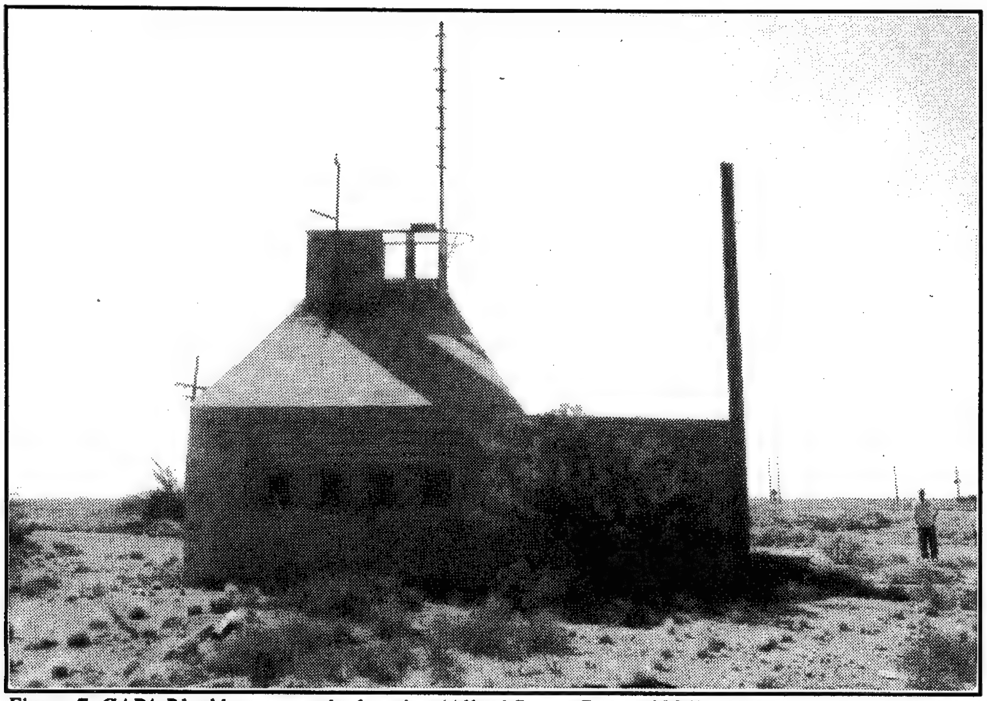


Figure 7. GAPA Blockhouse, north elevation (Allred/Space Center 1994).

pitched shed roof, and a single hung metal door centered on the south wall. Bent steel rod manhole steps extend up the north wall to a hand rail on the flat roof of the equipment room, then continue up the west slope of the observation room roof to the observation deck.[21] A 4' x 5' 6" semi-subterranean vault is attached to the west wall. Two wooden power poles (Feature 93) stand outside this room.

An instrument control box is located on the exterior north wall of the Equipment Room. A concrete-lined cable trench (Feature 85), 1' 6" wide and 2" deep, runs approximately 270 feet northeast through the center of the 100' square concrete firing apron (Feature 76/'Charley 2'). Pieces of the wooden trench cover are still in place. The firing apron has a 9' square, 6' deep vault in the center with a metal ladder descending to the bottom (Figure 8). The cable trench bisects the vault, and two iron tracks run across the top. Numerous iron tie-down stakes and metal plates are on the pad. Two brass caps set in the pad are inscribed with "BOEING RAMP HAFB INSTN 1948".

The cable trench continues northeast 140 feet to the edge of Lost River, where it ends at a 35' x 50' x 10' depression cut into the side of the river bank (no feature number was assigned). A dirt ramp leads out of the depression to the north into Lost River. The remains of cloth sand bags and oval chunks of concrete (apparently the contents of the sandbags) are imbedded in the ground along the walls of the depression. Sandbag depressions are also present in the concrete wall at the end of the cable trench. A metal culvert or conduit pipe extends from


Figure 8. GAPA firing apron and cable trench, looking northeast towards JB-2 launch ramp (Mertens/HAFB 1995).

the base of the concrete wall. Concrete blocks, lumber, and pieces of tarpaper roofing litter the bottom of the depression. This feature is shown on engineering plans as an unlabeled, u-shaped apron. [22] It has tentatively been identified as a munitions magazine. A May 1942 plan drawing for Building 1210 shows a 26' 6" x 12' 5" wood shingle structure on a concrete foundation. The structure is cut into a bank, with "brick or concrete blocks (cells filled with earth)" filling a 3' 10" space between the building and the excavated bank walls. Only the low gable roof extends above the bank on the remaining three sides, with the 10' high structure walls completely below the surface. [23] The feature may not be Building 1210, because the south facing door of that building does not correspond to the open north side of the feature and the 1942 date is not consistent with the GAPA testing. The building description, however, does fit the depression at the site, and it is possible a similar building was situated there.

Features 86 and 87 flank the depression. Feature 86 is a 21' 2" diameter, half-circle-shaped concrete pad with a 17' x 6' x 11' depressed apron extending from the center of the pad to the south. A metal frame is attached to the south end of the apron. Feature 87 is an 8' square concrete pad with a 3' square metal stand/frame in the center.

Two additional intact structures are in the area. Feature 92 (Cable Hut 1) is a 7' 4" x 7' 4" x 7' concrete structure with a low gable roof and single hung metal door in the north wall. Feature 99 is a 7' 9" x 7' 9" x 6' wooden platform with steps and a rail. A metal transit mount, situated over a brass cap, is in the center of the platform. The brass cap, inscribed with "MONUMENT NO. 4 HAFB 1948," is on the ground below the platform and is surrounded by a concrete pad inscribed with "A AM 8 MAY 66" and "FDE." Features 96 and 100, just south of the Building 1139 blockhouse, are identical to the generator pad, switch house, and substation identified in the NATIV complex. Feature 96 is a 16' square concrete pad. It probably once supported a tin switch house, but nothing remains of the structure. Feature 100 is a 10' x 6' 6" x 5' subsurface concrete vault with a tarpaper roof. Four bent steel manhole steps descend into the vault, which is surrounded by a 15' x 9' chainlink fence. A power line runs from this feature to the east.

Two features possibly representing the base of a launch ramp are located to the east of the Feature 76 firing apron. Feature 82 consists of eight 4' 2" square concrete pads arranged in two parallel lines of four in a 6' x 42' area. The southern two pads are closer together than the others. Just south is Feature 83, a 6' 6" x 4' 6" concrete ramp with two 1' square metal plates. The ramp slopes up towards Feature 82, with which it is probably associated. A wooden sled for transporting missiles or bombs is lying by the sloped ramp.

Twelve additional features are near the GAPA launch complex. These are listed in Table 3.

Table 3
Additional Features within the GAPA Complex

Feature No.	Description
7	Buried rocket base, 1' diameter with three 1' 11" fins. Dimensions match the booster from an Aerobee rocket (Figure 9).
81	Wooden power pole base.
84	Two wooden power poles 14' apart, attached at the top with a wooden platform. Platform probably for transformers.
88	2' 4" high metal pipe with platform. Probable camera stand.
89	30' square concrete pad with rebar in the center.
90	2'4" high metal pipe with platform. Probable camera stand.
91	Four 2' square concrete pads with metal plates in a 10' square area. Metal electrical box in center. Possible tower footings.
95	Two 5' x 2' 5" x 5" concrete pillars connected at the corner. One has a ventilator panel at the base, and the other an open metal chute.
97	Two iron gate posts with barbed wire. One post has gate hinges.
98	Wooden post in concrete.
102	7' square concrete pad with 4' square iron plate hatch cover with handles in the center. Possible vault.
104	9' x 8' x 6" concrete pad with wooden trough running to a wooden box within four 2' 6" concrete pads in a 9' square area. Possible tower footings with generator pad.

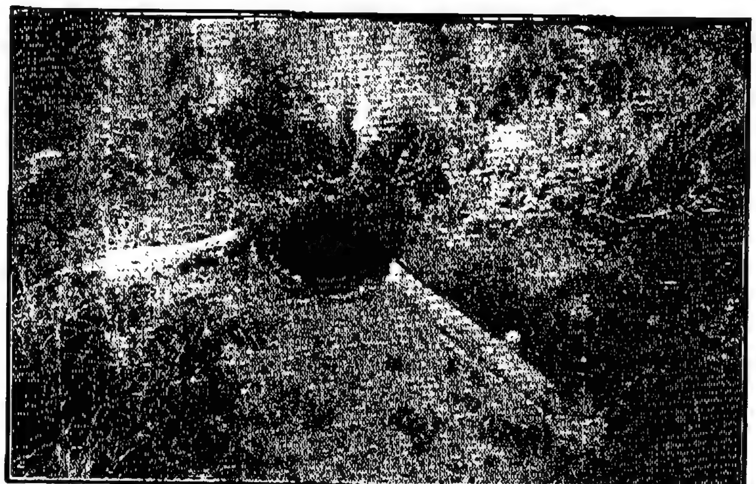


Figure 9. Possible Aerobee rocket booster imbedded in ground within GAPA complex (Tagg/HAFB 1995).

North American Test Instrumentation Vehicle (NATIV)

The NATIV complex is located within the MTSA, 1000 feet northeast of the GAPA complex and overlooking Lost River (see Figure 4).

Historical Background

North American Test Instrumentation Vehicle, or NATIV (pronounced native), was a missile program at HAFB in 1948. Officially, it was known as MX-773. Static firings started in January 1948 and the first flight took place in May 1948, with the final launching during November 1948.[24]

The NATIV was a vehicle about 14 feet long, weighed 1,260 pounds, had a range of 25 miles, and reached altitudes of 60,000 feet (Figure 10). Power was furnished by a liquid-fuel Aerojet rocket motor that burned 44-44 alcohol and red fuming nitric acid (RFNA). This combination was hypergolic, which meant it spontaneously ignited when the alcohol and acid were brought into contact with each other.

Launch was accomplished using a 182 foot tall launch tower completed on 20 September 1947 (Figures 11 & 12). The legs of the tower were mounted on concrete blocks and incorporated a tilting mechanism which allowed the tower to be tilted to a maximum of 18 degrees (Figure 13). The usual tilt during launch was 14 degrees to the northwest, aimed toward Mockingbird Gap at the north end of the Alamogordo Bombing and Gunnery Range. Since the range of the missile was 25 miles, and the distance from the launch site to Mockingbird Gap was approximately fifty miles, the impact point was apparently on the Range itself.[25] A blockhouse served as the remote control and launch point and afforded protection to the launch crew in the event of any mishap while the vehicle was on the launch pad (Figures 14 & 15).

After launch, the NATIV was tracked by SCR-584 radars, including one station located on Tularosa Peak. In addition to radars, phototheodolites were used to obtain flight data. There was no safety explosive destruct system on the missile. Should the missile stray from a safe flight path, a radio signal was sent to it causing the engine to shut off.

The test program called for 20 flights, of which only six were successful. The most successful was flight No. 3, which took place on 15 October 1948. The MX-773 program was changed in 1948 from that of a winged missile to a 1,000 mile test vehicle, later followed by a 3,000 mile test vehicle. These test vehicles were to be followed by a 5,000 mile operational missile. As a result of the NATIV tests, which led to the X-10 test vehicles and Navaho XSM-64, rockets were dropped as a means of cruise propulsion and were replaced by turbojets and ramjets.[26,27] The NATIV program was terminated in 1949.[28]

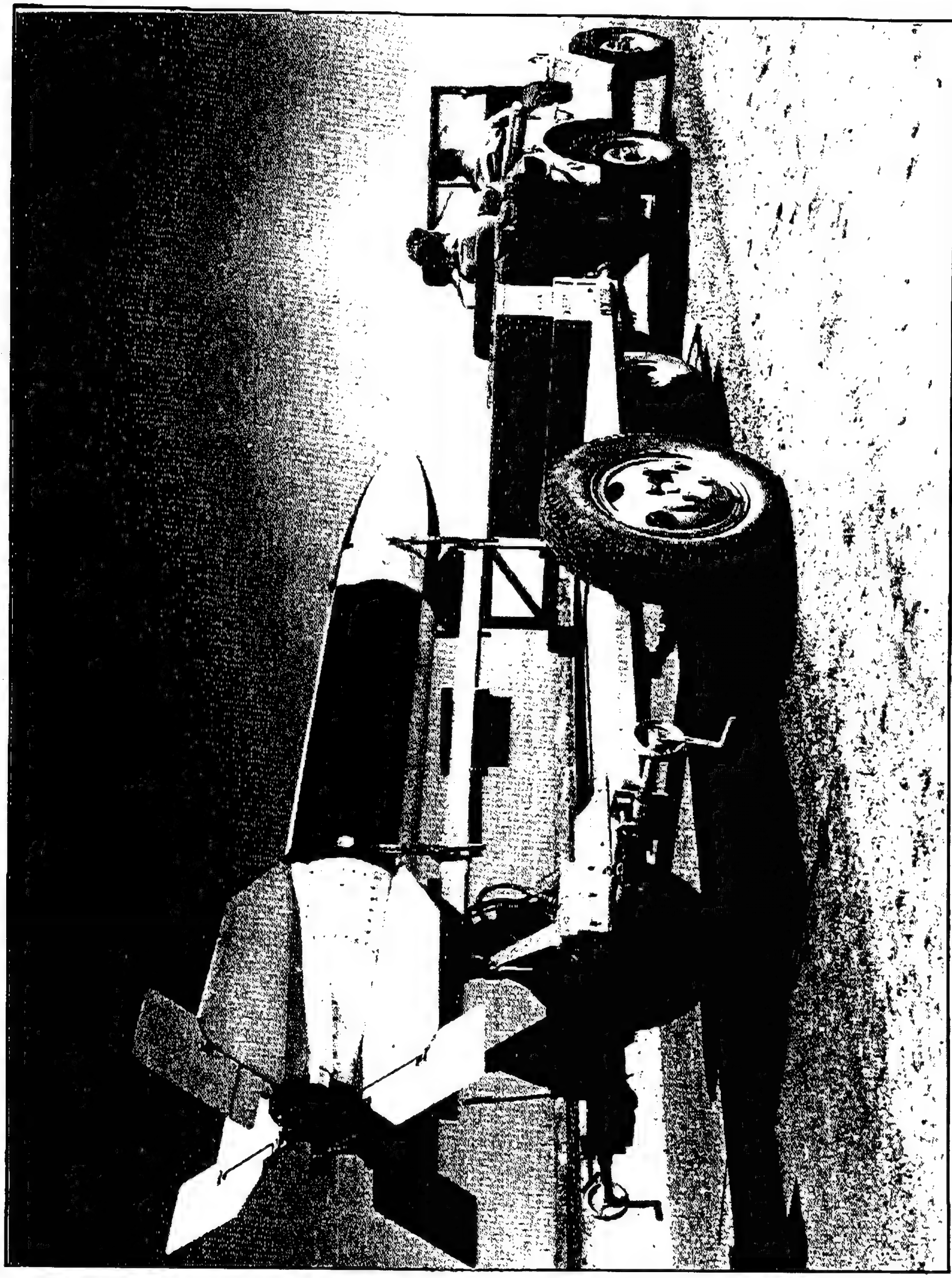


Figure 10. NATIV missile, ca. 1948 (Space Center archives 80-4089).

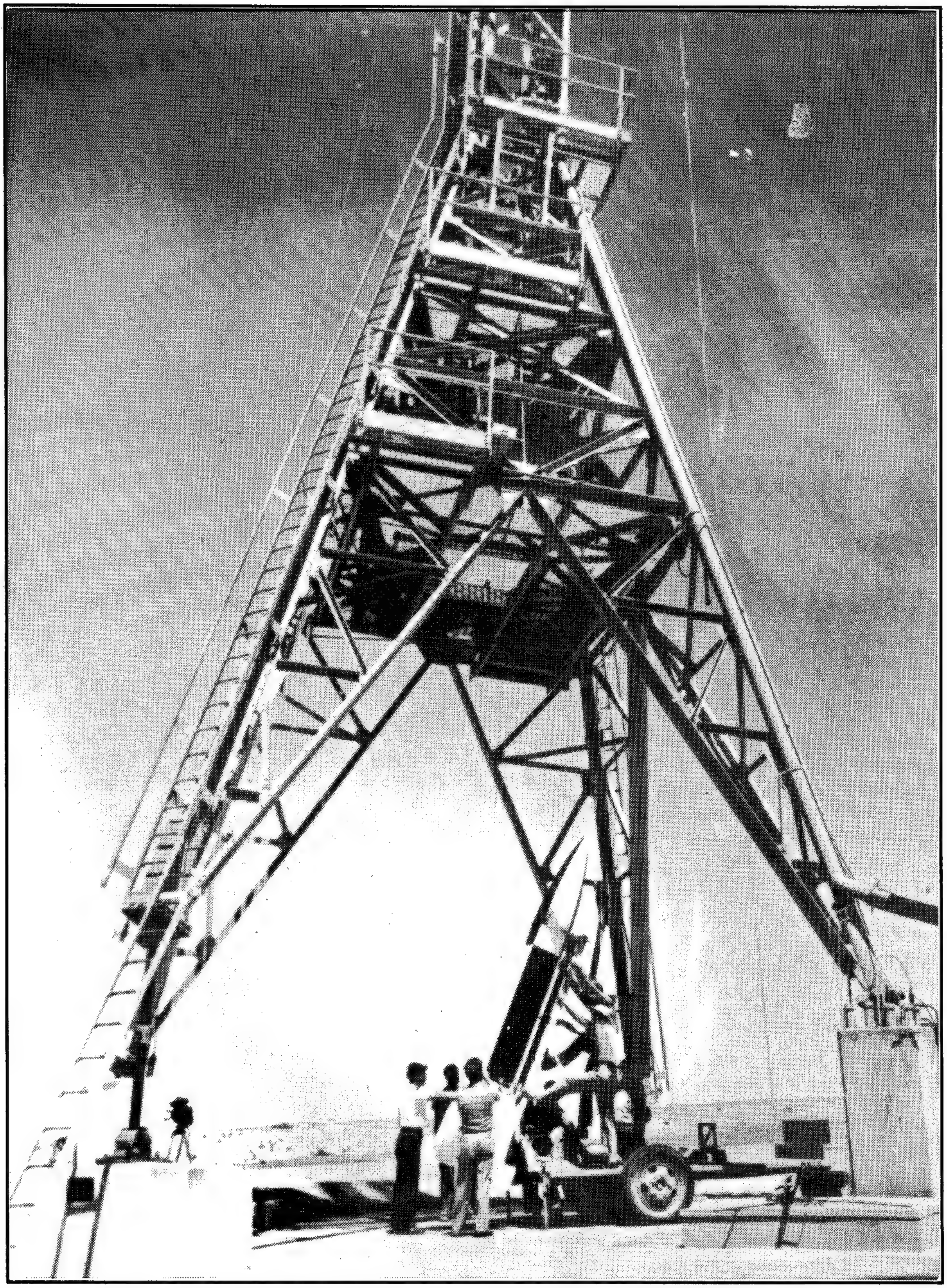


Figure 11. Loading NATIV missile on launch tower at the MTSA, ca. 1948 (Space Center archives).

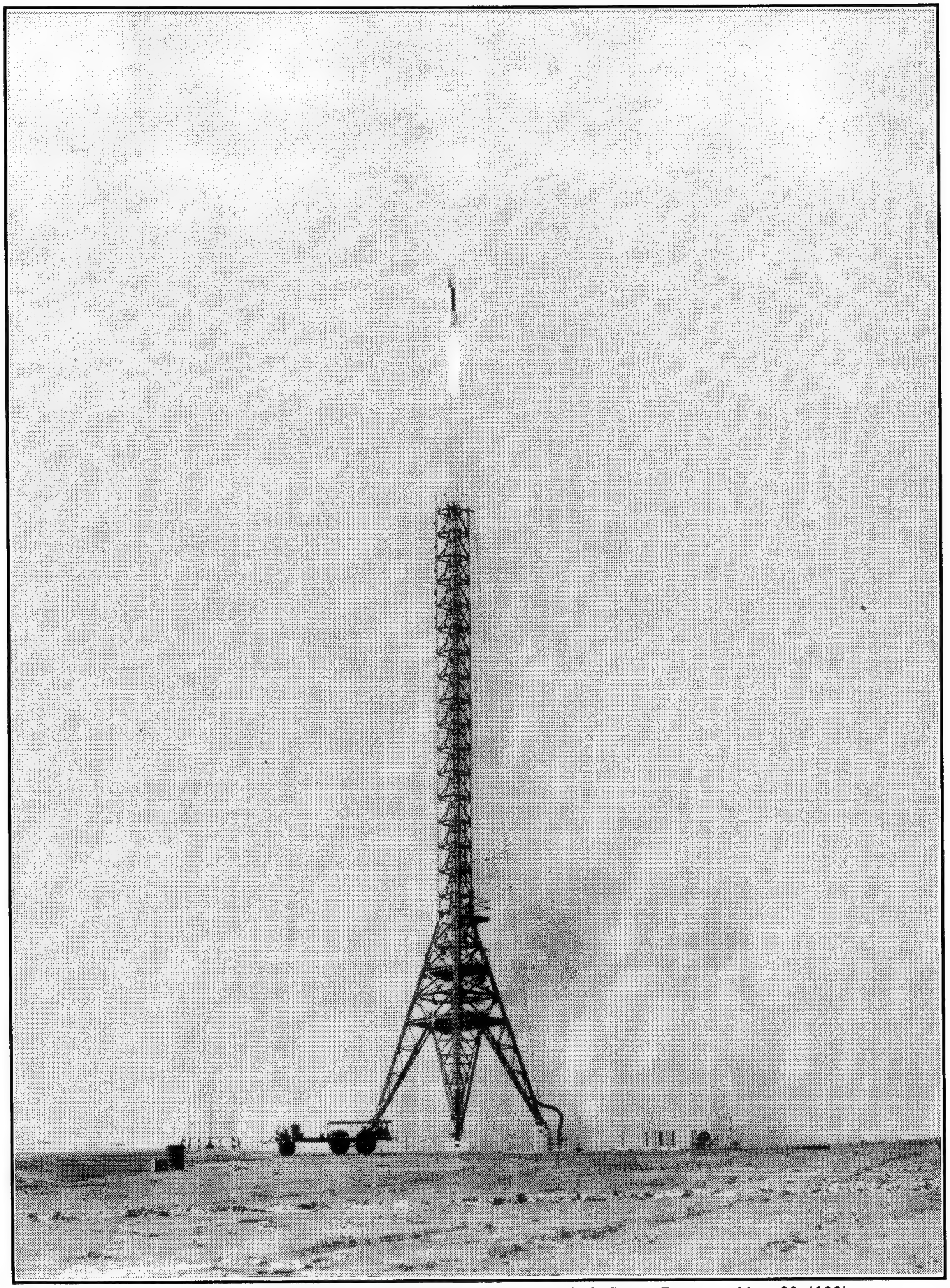


Figure 12. Launch of NATIV missile at the MTSA on HAFB in 1948 (Space Center archives 80-4100).

Figure 13. Remains of NATIV tower jacking mechanism (Allred/Space Center 1994).

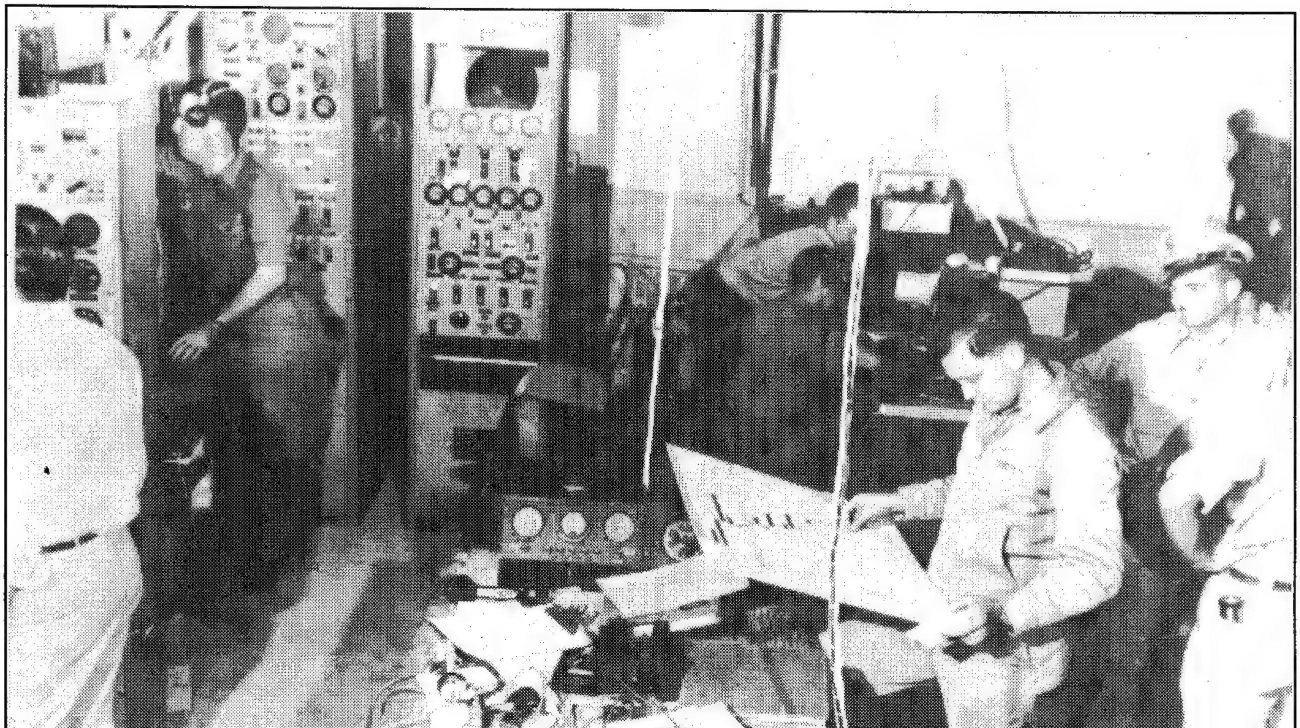


Figure 14. Inside NAA NATIV blockhouse during countdown, ca. 1948 (Photo courtesy of Robert Montogomery).

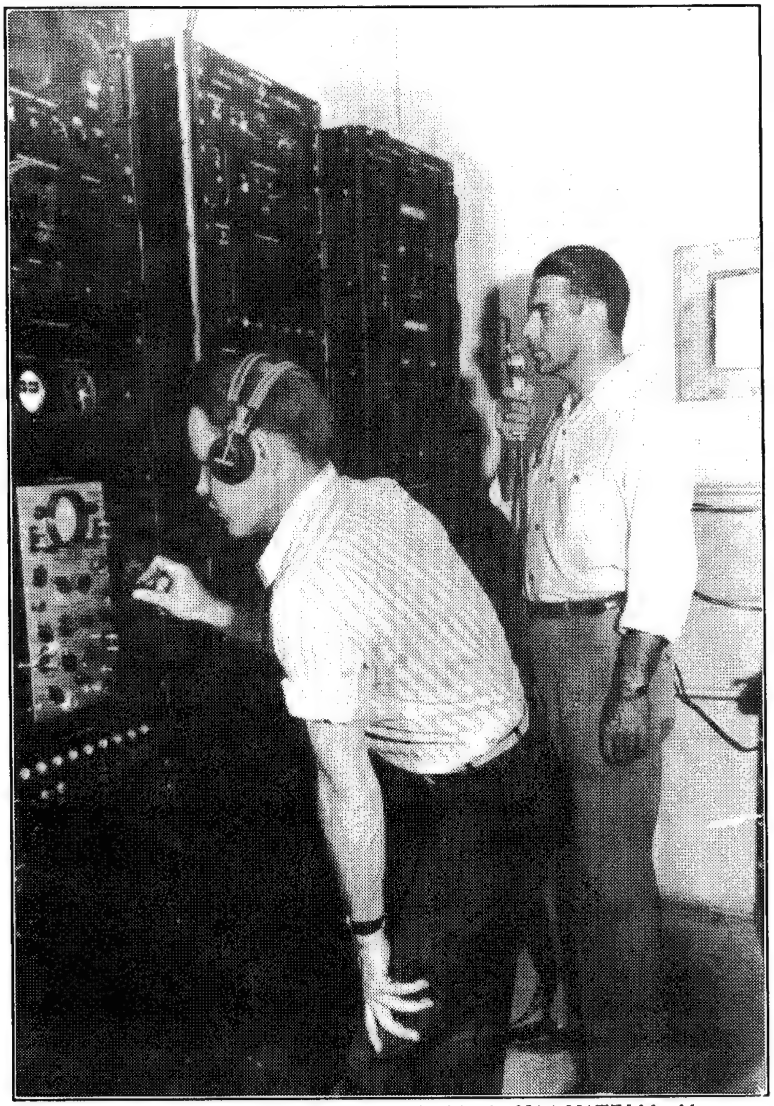


Figure 15. Instrumentation timing system inside the NAA NATIV blockhouse, with Robert Montgomery and William Cox, ca. 1948 (Photo courtesy of Robert Montgomery).

Archaeological Perspective

The NATIV launch complex consists of three intact buildings, three launch pads, and a number of noncontagious features in a 600' x 400' area (Figure 16). From a 1947 plot plan, the original facility consisted of the control house, static test pad, and the firing apron with a cable trench connecting them. [29] The control house, or observation shelter (Building 1116/Feature 55/'Baker 1'), is a steel-reinforced cast-concrete, one-room rectangular structure (Figure 17). The control room measures 34' x 21' and has 846 SF of interior space. The building is listed in real property records as being completed in 1949, and originally it had 891 SF with a 13' x 20' offset (equipment room?). "Subsequent improvements through May 57" reduced the building to its current size. [30]

Building 1116 has 3' thick walls and a high, truncated hip roof. A single hung steel door is centered in the south wall under a cast concrete breezeway with a low pitched shed roof (Figure 18). A 10' square concrete pad runs east of the entryway. Bent steel manhole steps ascend the center of the east wall to the observation deck on the flat roof top. The deck is enclosed with a metal rail. Four rectangular, inset observation windows, three in the north wall facing the launch pad and one in the west wall, have 5" thick panels of plate glass which are pocked with bullet holes. [31,32,33] Exterior instrument control boxes are located at ground level below each of the three northern windows. A concrete cable trench, 1' wide and 2' deep, runs 50 feet north from the eastern control panel on Building 1116 to a 40' square, 6" thick concrete apron with a static test pad (Feature 56). The pad has a concrete conduit vault and footings for at least one, and perhaps two, towers (Figure 19). The cable trench (Feature 54), once protected by a wooden cover, continues north 100 feet from this pad to the east side of the 100' square concrete firing apron (Feature 57/'Charley 1'). Four rebar-reinforced concrete tower footings are all that remain of the 182' tall tower which once stood there. Two pillars are 2' 8" square and 6' 2" high with swivel tower mounts and conduit vaults beside

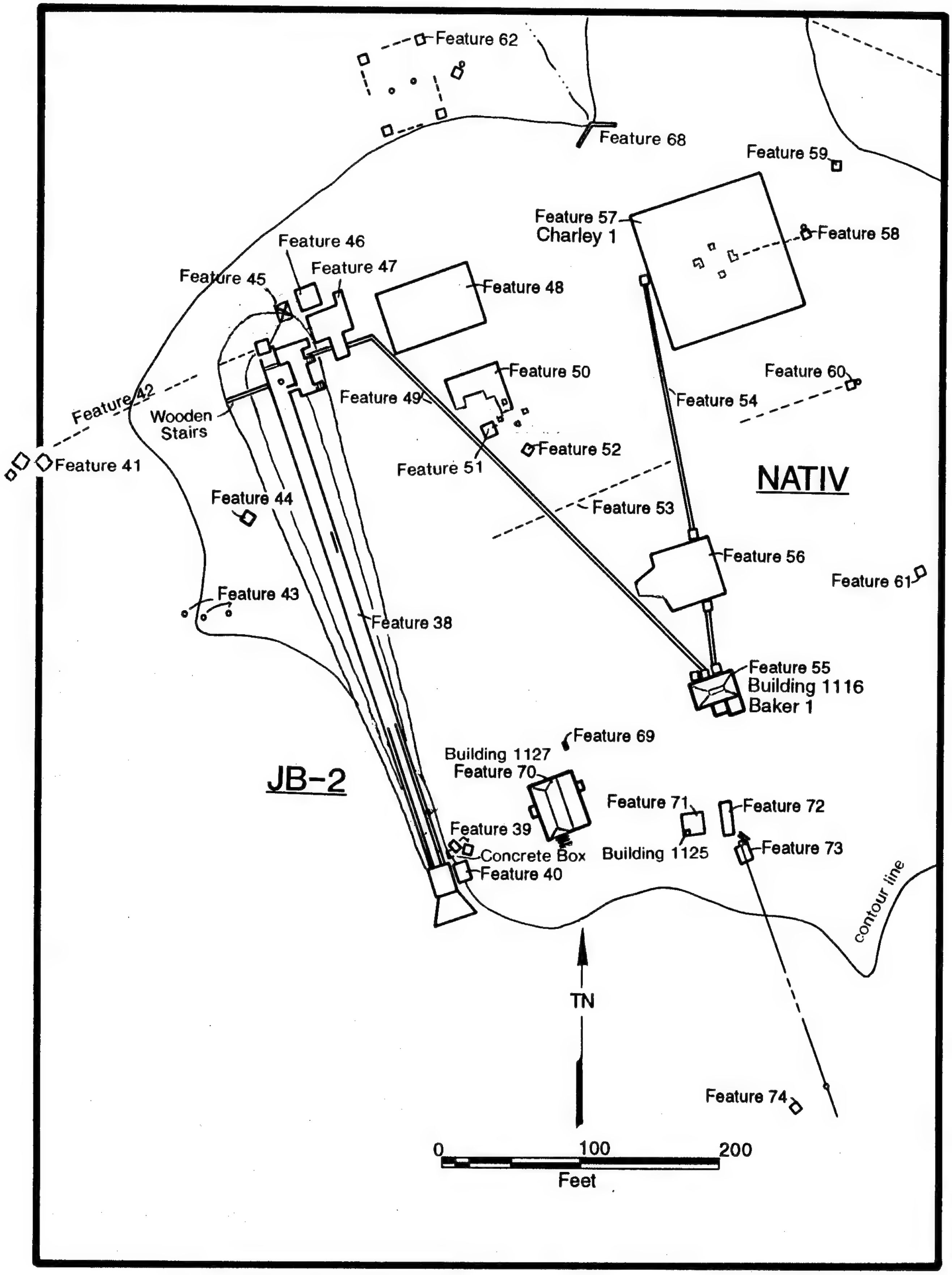


Figure 16. NATIV and JB-2 complexes map (adapted from Eidenbach and Wessel 1995).

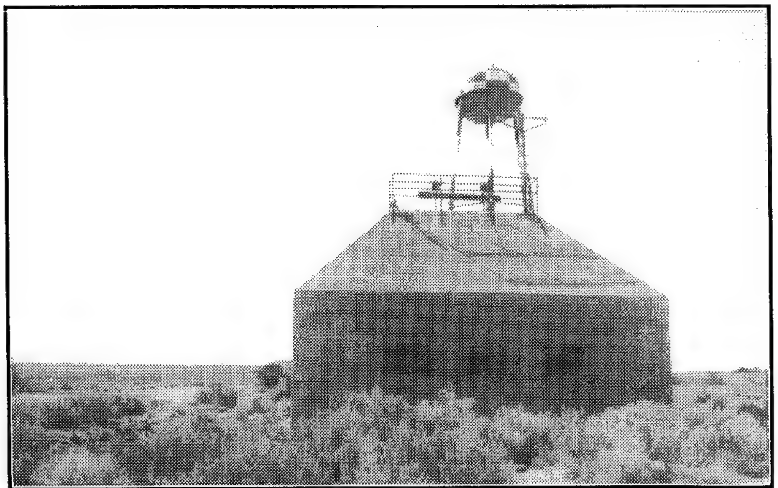


Figure 17. NATIV/JB-2 blockhouse, north elevation, with a later constructed water tower in background (Allred/Space Center 1994).

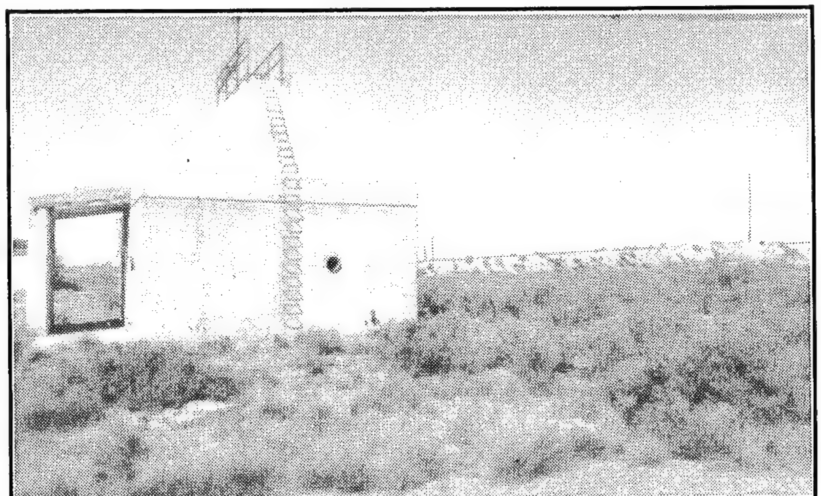


Figure 18. NATIV/JB-2 blockhouse, east elevation, illustrating manhole steps. JB-2 ramp in the background (Allred/Space Center 1994).

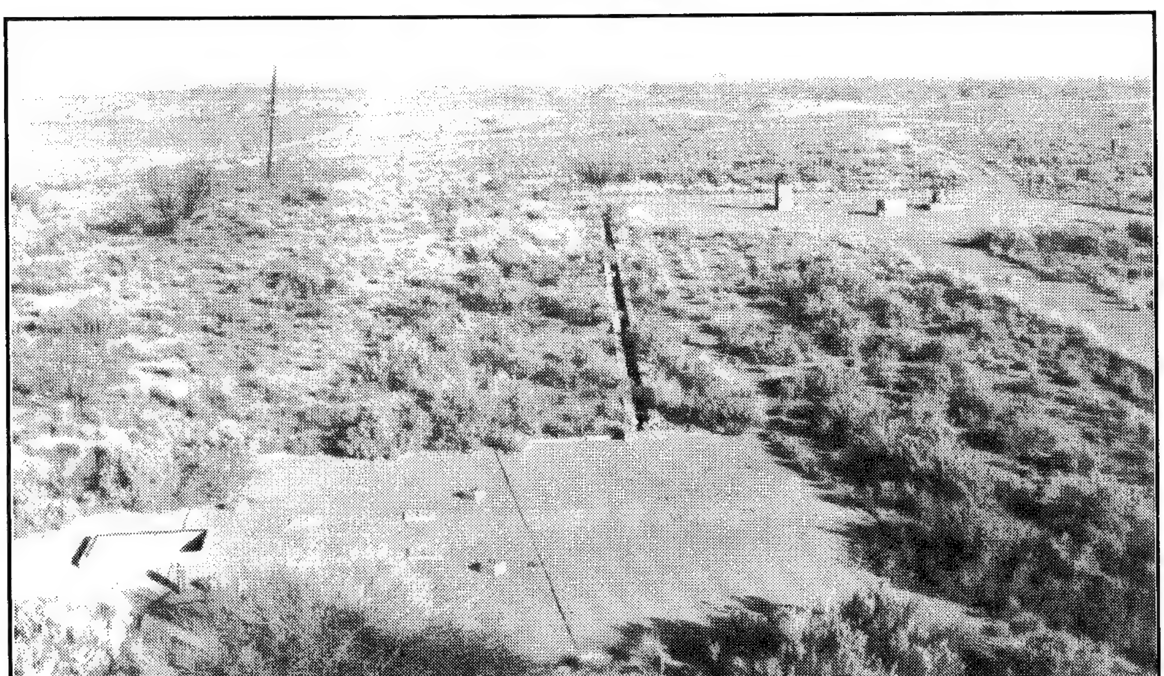


Figure 19. NATIV static test pad (foreground) and firing apron connected by a cable trench, looking north from the observation shelter (Mertens/HAFB 1995).

them. The other two are 4' 5" square and 3' high with a slight slant to the center of the pad. One each of the two types of footings have been destroyed. A brass cap set in the center of this pad is inscribed with "MONUMENT NO. 3/N.A.A. TOWER/H.A.F.B. 1948."

A 6' square concrete vault with a water valve in it, a wooden cover, and a metal upright pipe (Feature 58) is just west of the firing apron. It may be the fire plug mentioned on the 1947 plot plan.[34] A subsurface line runs from this feature to one of the tower footings on the firing apron. Two more of these possible deluge features (Features 60 and 61) are located to the south. A 1' square concrete pad with a gridded steel plate lid, perhaps a calibration plate (Feature 59), is also east of the firing apron.

A second, partially buried, cable trench (Feature 49), illustrated on the 1947 plot plan as "cable trench to future test stand," runs about 340 feet from the center control box on Building 1116 under a probable launch or static test pad (Feature 47) and into the concrete platform on the JB-2 launch ramp.[35] The concrete pad is approximately 29' x 20' with a 12' x 8' extension to the north and a 6' x 8' extension to the south. This feature may have been the tie-down pad for a B-25 bomber, which was used to launch Falcon missiles in the late 1950s by the Hughes Aircraft Company. The Falcon was the world's first operational guided air -to-air missile, and it was apparently tested on HAFB beginning in the late 1940s. The Falcon program was not investigated as part of the current project, so further research will be necessary to determine its use on HAFB and in the JB-2 and GAPA complexes. Eight additional features are in the vicinity of Feature 47 and the north end of the JB-2 ramp. These features are listed in Table 4.

A final series of features is located between the JB-2 loading pit and Building 1116. A July 1954 site plan shows new construction of a Rocket Motor Conditioning Building (Building 1127) and a Generator Pad and Switch House (Building 1125).[36] Building 1127 (Feature 70) is still intact and appears relatively unmodified. The two-room, 1427 SF structure was completed in 1955 and consists of a concrete foundation and floor, concrete and asbestos shingle walls, and an asphalt roll roof. The main building, with 1' thick concrete walls, measures 20' x 43', has a low gable roof, and double hung metal doors with a concrete ramp opening to the west. A roofed ramada was once attached to the south wall, but only the four concrete ribbon footings remain today. The second room, with asbestos shingle walls and a low-pitched shed roof, is 13' 6" by 42' with double hung metal doors and a ramp opening to the east. An air cooler illustrated beside this door in the plans is no longer present.[37,38]

Building 1125 (Feature 71), the Generator Pad with Switch House, is also intact.[39] A 4' 8" x 6' 9" x 8' corrugated tin shack with a slightly pitched, asphalt tar paper shed roof sits on the southwest corner of a 16' square concrete pad. The shack has a doorway on the north side and an electrical switchboard box in it.

Two additional features shown on the 1954 plan include a generator pad (Feature 72) and a substation (Feature 73).[40] Feature 72 is a 24'6" x 8' concrete pad. Feature 73 is a 10' x 6' 6" x 5' deep subsurface concrete vault with a tarpaper roof. Four bent steel manhole steps descend into the vault, which is surrounded by a 15' x 9' chainlink fence. A transformer panel, with four fuse boxes, is between the two features, and a power line runs from this panel to the south.

Table 4
Additional Features within the NATIV Complex

Feature No.	Description
46	Electrical station with 11 '6"' x 6' 6" concrete pad within a 20' x 8' chainlink fence. Angle iron frame for supporting transformers is on pad, and "DANGER 13,200 VOLTS" sign is lying beside fence.
48	70' x 45' concrete pad.
50	39' x 18' 6" concrete pad with two 6' square and one 19' 6" x 9' pads attached on the south end of the pad. Four 2' square concrete tower footings with rebar in a 20' square area intrude on the south end of the pad.
51	8' square concrete pad with two metal tie-downs.
52	4' 9" x 2' 6" x 1'8" u-shaped concrete pillar with heavy iron mounts on each end.
53	Linear depression bisecting the NATIV cable trenches. Probable underground utility line. The line runs to Feature 60.
62	Possible tower footings. Four 3' square concrete footings in a rectangular 57' x 46' area with two angle iron uprights in the center. A wooden pole and 4' square concrete pad to the east.
68	V-shaped, concrete and stone culvert wall at the head of a small erosional channel above a large trash scatter of wooden debris. Wing walls are 18' and 20' long, 2' 4" high, with a 1' 6" diameter concrete culvert pipe in the center. Inscriptions of "5/28/48" and "19 H 8" are in the top of the wall.

Jet Bomb 2 (JB-2)

The JB-2 complex is located adjacent to the NATIV complex within the MTSA overlooking Lost River (see Figure 4). The JB-2, an American version of the German V-1 used during World War II, was tested at HAFB in 1948.

The German Vengeance Weapon (V-1)

On 12 June 1944, the English people were subjected to the first attacks by German surface-to-surface guided missiles known as the V-1 or Vergeltungswaffe 1 (Reprisal or Vengeance Weapon 1).[41] The citizens of London, against whom the weapons were aimed, called them Doodlebugs.

The V-1 could probably be called the pioneer cruise missile and it stemmed from the pulse-jet research begun by aerodynamicist Paul Schmidt in 1928. In 1939, the German Air Ministry asked for and received a pulse jet engine which was rated at 660 pounds thrust at sea level. This engine had a grid of flap-valves in the inlet, which would open to permit air to enter the engine. The valves were forced shut by the pressure resulting from ignition of the air-fuel mixture in the duct. The opening and closing of the flap-valves operated at a frequency of about 47 Hertz and caused a great deal of noise and vibration.[42] This engine was married to an airframe produced by the Gerhard Fieseler Werke and the result was the Fieseler Fi 103 (Figure 20). As a cover, the project to develop this weapon was called FZG-76 (Flakziegerat, flak aiming device). Production was primarily accomplished at the underground factory called Mittelwerke near Nordhausen, with production elsewhere being done by Volkswagen at Fallersleben and Fieseler.[43]

As the war began to go against Germany in the early 1940s, the Nazi government determined that if it were going to force England to the peace table, it needed to find ways of attacking them on English soil. Conventional artillery did not possess sufficient range to permit the shelling of London and Southern England from either Germany or France. The Germans had also learned the hard way in the Battle of Britain that its air force, the Luftwaffe, could not bomb England into submission. Therefore, attention was turned toward the development of a missile with enough range to carry a large explosive warhead across the English Channel. The initial suggestion for such a missile was rejected by the German Air Ministry in September 1941. On 5 June 1942, the Fieseler Aircraft Works in Cassel again offered to develop a missile suitable for use against London. This time the offer was accepted.[44]

The Germans launched 10 of these guided missiles against England on 12 June 1944. Four crashed shortly after becoming airborne, but six of them headed for England.[45] These attacks increased in ferocity so that by 21 June, a total of 1,000 had been launched. Just eight days later the 2,000th V-1 had been launched.[46] Between June and September 1944, a total of 5,430 V-1s were fired against England, causing 6,100 deaths and 17,300 injuries, and destroying or damaging one million buildings. The German plan had been to launch up to 5,000 V-1 missiles against England every 24 hours. The Germans were unable to attain that goal, however, because of subsequent heavy Allied bombing of V-1 launch

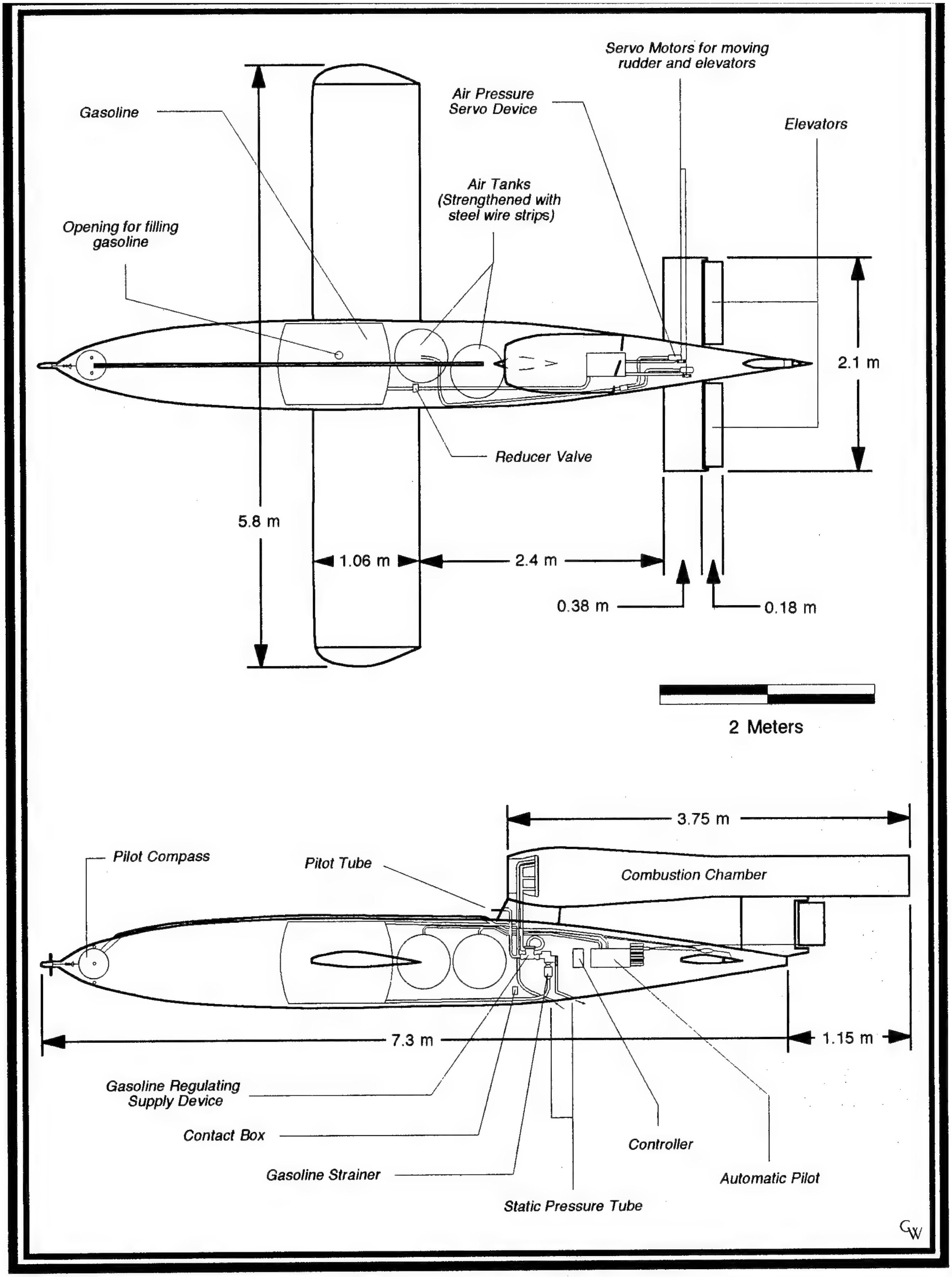


Figure 20. V-1 schematic drawing.

sites and invading Allied forces pushing the Germans beyond the V-1's effective range. [47]

Fieseler Fi-103 missiles (V-1s) were launched by catapult under their own power. [48] Later, after the Allies overran the launching ramps in Northern France and Holland, V-1s were launched from Heinkel He-111 aircraft over the North Sea. Only about 80 of these air-launched missiles (about 56 percent) reached London. [49] Toward the end of the war, 8,691 V-1s were launched against Antwerp, Belgium, which the Allies were using as a supply port, and 3,141 against Liege, Belgium, an Allied supply base. The last use of the V-1 was in the Ardennes of northeast France and in the Rhine Valley of Germany. However, the V-1 did not have a decisive effect in those campaigns. [50]

Another proposed use for the V-1 called for a piloted version known as the Fieseler Fi-103R IV (Reichenberg). The procedure for using this weapon called for the pilot to aim the craft at the target, release the cockpit canopy, and bail out at the last moment. With the engine inlet immediately behind the pilot, it seemed the pilot had little chance to escape. The Germans realized this fact and the 70 pilots selected for this program became known as Selbstapfermanner (Self-sacrifice men). Bail out problems and official conflict over a suicide craft resulted in this version of the V-1 never being used operationally. [51]

The American Jet Bomb 2

The AAF received salvaged remains of a German V-1 in 1944 from the underground forces in Europe who had witnessed the impact of a V-1 and were successfully able to hide the vehicle from searching German forces. The remains were then clandestinely airlifted out of occupied Europe by the British Royal Air Force and transferred to the United States. In 17 days the AAF was able to reverse engineer the airframe and the engine. Evaluation of this weapon system resulted in the War Department allocating $90 million in July 1944 for the Jet Bomb 2 (JB-2), nicknamed 'Loon' (Figure 21). The Loon was officially designated as weapon system MX-544. The contract to produce the Loon was awarded to Republic Aircraft. Republic subcontracted with Willys-Overland for the airframe, Ford Motor Company for the engine, and Northrop for the launch sleds. [52, 53]

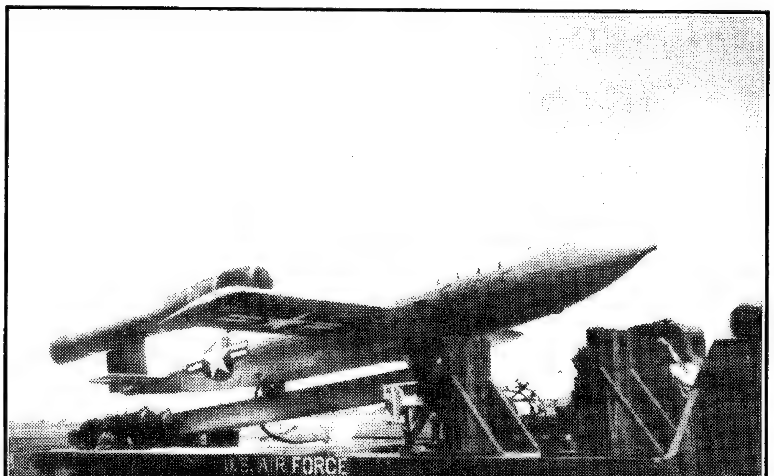


Figure 21. A JB-2 Loon at Bolling AFB, Washington, DC, May 1950 (Photo courtesy of Wayne O. Mattson).

There were differences between the German V-1 and the American JB-2, primarily in the areas of launching and guidance. The Germans used a ramp with a six degree slope and a combination of hydrogen peroxide and potassium permanganate for boosting the V-1 up to the minimum safe launch speed of 200 miles per hour. The AAF felt this combination was too dangerous and turned

to powder (solid fuel boosters). [54] For guidance, the Germans used a gyro autopilot, powered by compressed air, to hold a course determined by a magnetic compass. A barometric device controlled altitude. A small propeller armed the warhead after the V-1 flew about 38 miles and then, after a preset number of turns, it fired two detonators which locked the elevators and rudder in the streamlined position and the device simultaneously deployed hinged spoilers on the tail. This caused the V-1 to pitch down, presumably over the target. This pitch-down usually cut the fuel flow to the engine, causing it to stop, warning those on the ground of the impending explosion. [55] American attempts to use similar guidance resulted in a Circular Error of Probability (CEP) of about eight miles in a 127-mile range. This resulted in the AAF changing the method of guidance to radio control, which eventually reduced the CEP to a quarter of a mile at a 100-mile range. [56] A comparison of the V-1 and the JB-2 is reflected in Table 5. [57,58]

Table 5
V-1 and JB-2 Comparison

V-1		JB-2
17' 4-3/4"	Wing Span	17' 8-1/8"
25' 11"	Length	27' 1-1/16"
4,806 lbs	Weight	5,025 lbs
149 miles	Range	150 miles
2,493'	Ceiling	6,000'

Early versions of the JB-2 experienced problems because of construction with inferior components and the use of an unreliable autopilot. The AAF ordered the missile into production in spite of the problems and wanted 500 missiles produced per day. The War Department ordered a total of 5,000 missiles. The contract, however, was cancelled when World War II ended. By the time the contract was terminated in mid-September 1945, the AAF had accepted between 1,385 and 1,391 JB-2s. [59,60] When the war ended in Europe, the United States had JB-2 crews on transport ships heading for the Japanese Theater of Operations. The plan had been to saturate Japan with thousands of JB-2s prior to an invasion. [61] The dropping of atomic bombs on Hiroshima and Nagasaki, Japan cancelled that plan.

The first test flight of the JB-2 took place at Eglin AFB, Florida, on 12 October 1944. The first American air launch of a JB-2 was made from a B-17 on 2 March 1945. Plans were developed to launch the JB-2 from the back of a B-24, but this concept was scrapped as being too dangerous. [62]

The AAF continued the JB-2 tests at Wendover AFB, Utah, after the end of World War II. In late 1947 the USAF decided to transfer guided missile tests to Alamogordo Air Force Base (AAFB) in New Mexico. One of the programs transferred was the JB-2. The JB-2 was launched from a 400 foot long track at Wendover AFB and the rails from this track were transferred to AAFB and used in the construction of the JB-2 ramp at the new location. [63] The existing NATIV blockhouse was used as the control center for the program (see Figures 17 & 18).

JB-2s were launched at AAAB from a 392' 2" ramp with rails using a sled (Figure 22). The sled was primarily a tubular device mounted by means of drop pins to the fuselage of the JB-2. The sled extended from approximately the leading edge of the wing to the tail of the missile. A crosspiece at the front of the cylinder provided mounting points for the front slippers, which fit on the launch ramp rails. The aft attachment point was located approximately at the leading edge of the engine inlet. The sled continued back, and the aft crosspiece contained the aft slipper and the mounting portion for the four Rocket Assisted Take-Off (RATO) solid fuel boosters used to accelerate the JB-2 to launch speed (Figure 23). [64]

Although the JB-2 project arrived at AAFB in March 1947, the first launch did not take place until May 1948 because the Air Force could not launch any Loons until the launch ramp was completed. The JB-2 project had actually been cancelled before it was moved to Alamogordo, but the Air Force continued with the test series in order to complete the program. A total of 11 launches were accomplished at HAFB, with the last two in October 1948. [65] On occasion it was necessary to borrow safety chase aircraft from another base to support the JB-2 launches. Two F-80 aircraft were borrowed from Williams AFB, Arizona, for a July 1948 launch. [66] Brief consideration was given, in November 1948, to the possibility of using the JB-2 in support of the Matador Project. However, this failed to revive the JB-2 program. [67]

Archaeological Perspective

The JB-2 Loon launch complex consists of the launch ramp and numerous features in a 500' x 200' area (see Figure 16). From 1947 and 1948 plans, the original launch facility, designated 'Charlie 1', included the launch ramp and a reinforced concrete box. The earthen ramp (Feature 38), facing 330 degrees, is 440' long and ranges in width from 10' at the beginning to 80' at the end (Figures 24 & 25). The ramp bed is inclined at a 3 degree slope, starting at the existing ground surface and rising to a height at the end of approximately 24'. Two parallel, 75-pound ASCE (American Society of Civil Engineers) rails 4' 11" apart, run for 392' 2" along the top. The track sits on 18" tall steel I-beams resting on 77 standard, 8" x 1' x 7', wooden cross-ties. A bed of 10" thick reinforced concrete was poured over a compacted subgrade between the I-beams. [68] Only 105' of rails remain at the southern end of the track, with the remainder cut off and removed at some time in the past. A single rail also remains in the center of the ramp.

A rectangular concrete loading pit with a flared apron is situated at the southern end of the ramp. The pit is 20' x 16' x 3' 3" deep with 8" thick concrete walls. It was apparently open to the south where the apron connected. The apron is 20' long and 34' wide at its widest point. Modern trash has been deposited in the pit. The "reinforced concrete structure" is situated adjacent and east of the loading ramp, although the original plans and an early photo show it on the west side and a later plan illustrates one on each side (see Figure 22). This u-shaped structure has 8" thick walls and floor and inside dimensions of 6' x 4' x 4' deep. [69,70,71,72]

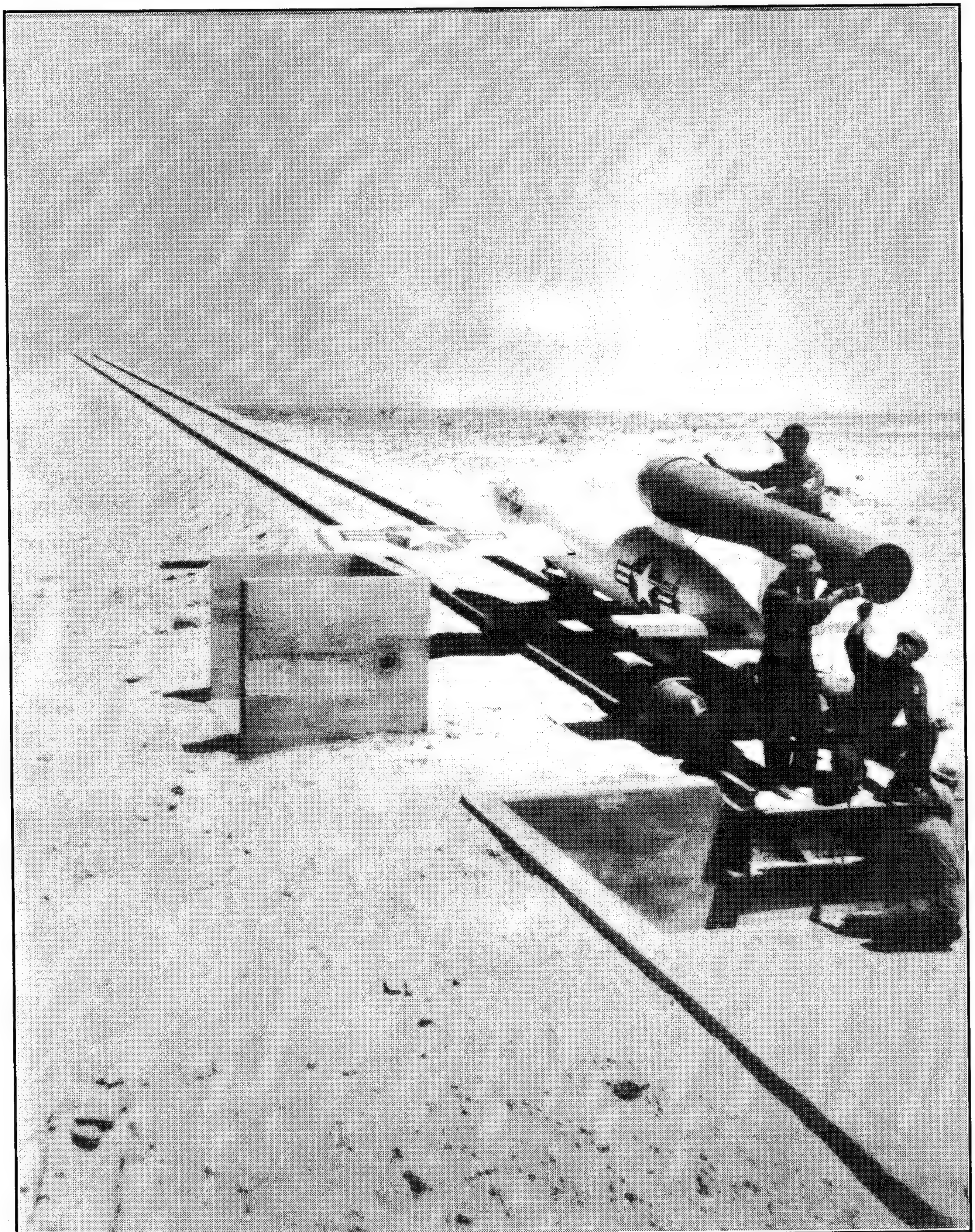


Figure 22. JB-2 Loon on launching ramp at HAFB, ca. 1948 (Space Center archives).

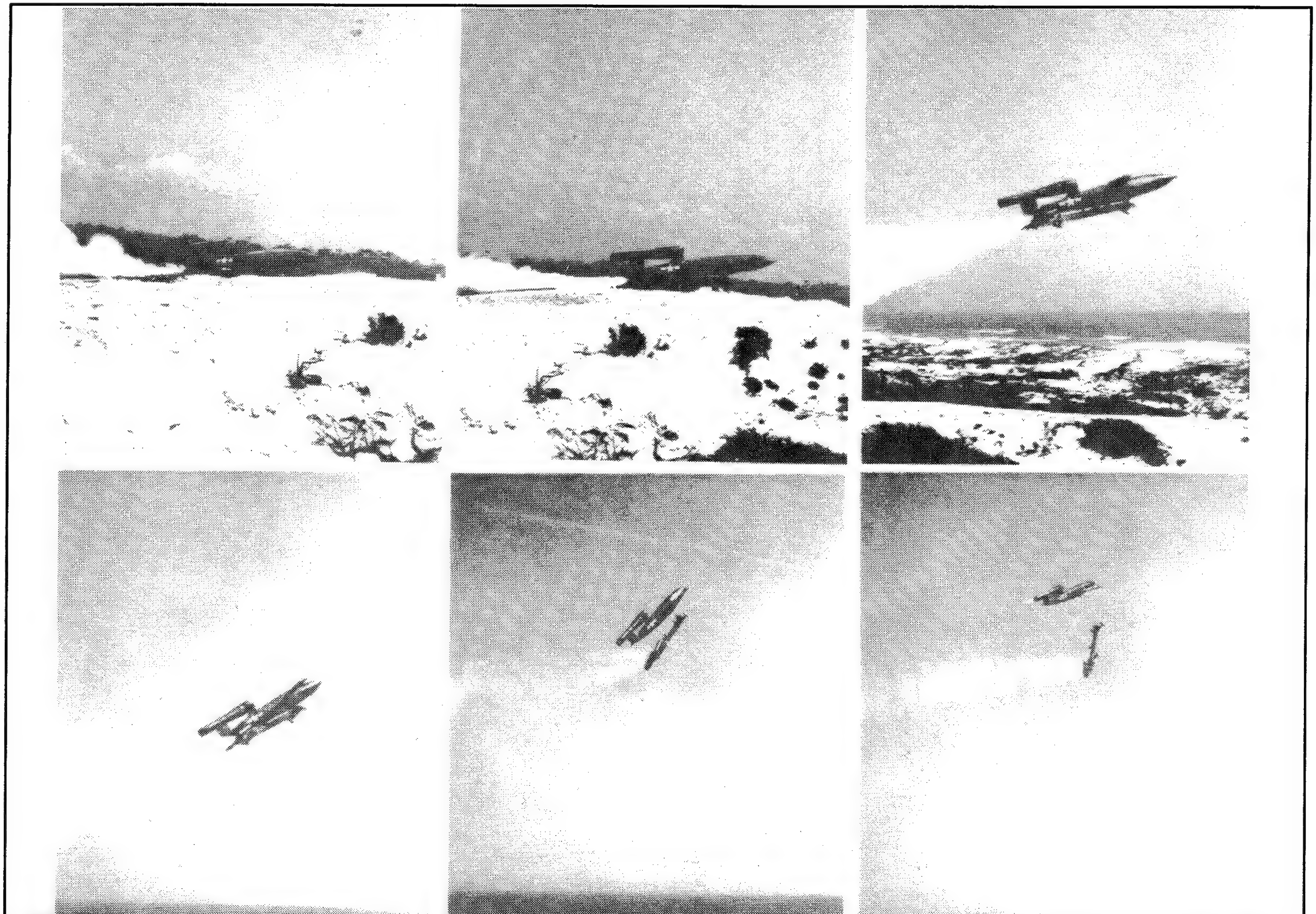


Figure 23. A JB-2 launch at Eglin Field, Florida, using a rocket-assisted-take-off (RATO) assembly, ca. 1945 (Photo courtesy of Eglin AFB History Office and Dr. Newell Wright).

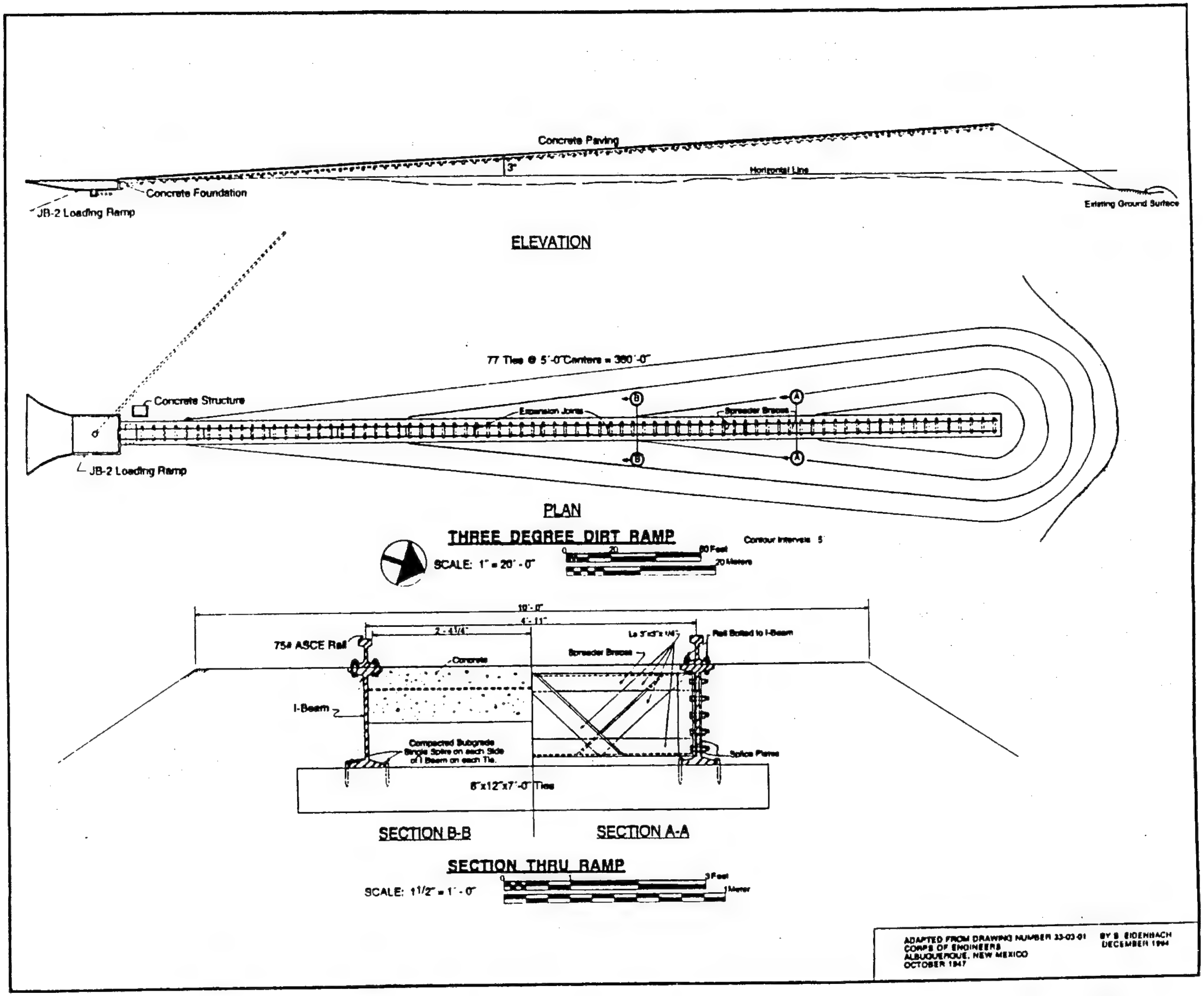


Figure 24. 1947 JB-2 launching ramp plan (adapted from U.S. Army Corps of Engineers drawing by Eidenbach and Wessel 1995).

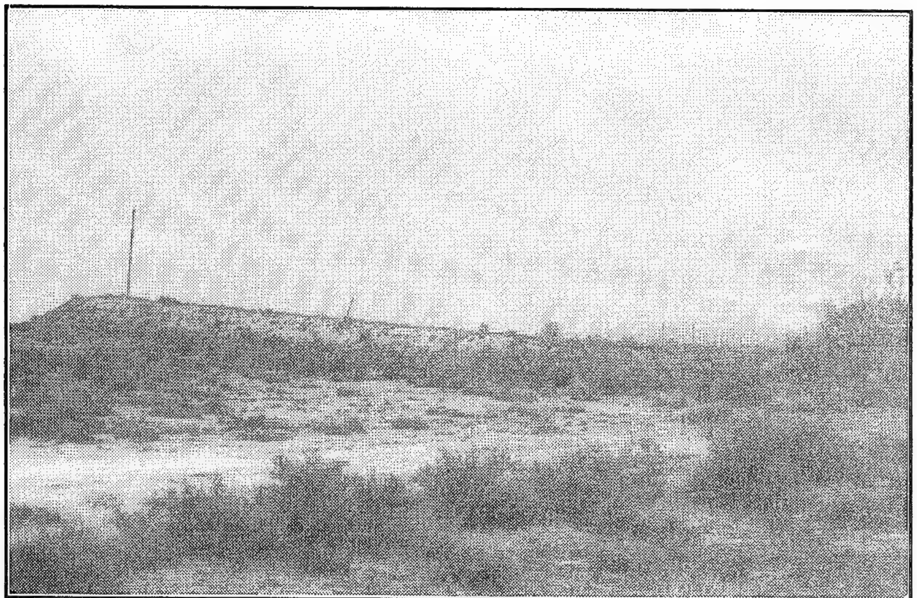


Figure 25. The JB-2 launch ramp in the MTSA, west profile (Tagg/HAFB 1995).

A number of features on the JB-2 ramp were added after the original ramp construction. At the north end of the ramp, a concrete stairway leads down to a 40' x 20' concrete structure pad cut into the earthen ramp. The pad is elevated about 4' above the present ground surface with two sets of concrete steps running to the ground. A portion of the concrete superstructure of this pad and a large chunk of the dirt ramp around the concrete modifications has collapsed (Figure 26).

A 5' x 10' concrete pad has been added to the end of the rails and 2" x 10" planks extend from this pad to a metal tower situated just off the end of the ramp (Feature 45). The top of the tower is level with the top of the ramp. It has four legs, 8' apart, is constructed of angle iron, and has a metal ladder and a metal grate platform surrounded by a wooden frame. A wooden stairway was constructed off the west side of the ramp, and a wooden flume (Feature 42) runs from a channel between the end of the rails and the new pad to three concrete pads 170 feet west of the ramp (Feature 41). The concrete loading pit has also been modified. The height of the walls has been extended 4', encasing the southern end of the rails (Figure 27). The southern end of the structure has been enclosed and a 6' 4' x 5' 4" doorway is in the center of this wall.

The ramp modifications were apparently made by the Hughes Aircraft Company in the later half of 1950 for the Falcon missile program. The modification was done to permit the installation of a hot and cold chamber for temperature cycling of rocket motors used in the early stages of the program. The temperature cycled rocket motors were then used during Falcon missile launches from a B-25 which was tied down to the right of, and just short of, the northern end of the JB-2 ramp (Feature 47 in the NATIV complex). [73] Variants of Falcon missile continued to be tested up through the 1970s.

Four additional features close to the ramp which may or may not have been associated include: a 3' 5" square concrete electrical control and valve box (Feature 39) and a 10' x 15' concrete pad beside the loading pit (Feature 40), and a 7' square concrete pad with 2' x 4' lumber debris (Feature 44) and three wooden poles (Feature 43) to the west of the northern half of the ramp.

Although no wreckage was noted on the site, an intact JB-2 Loon, at one time exhibited in 'Missile Row' along HAFB's main gate, is currently curated at the ISHF.

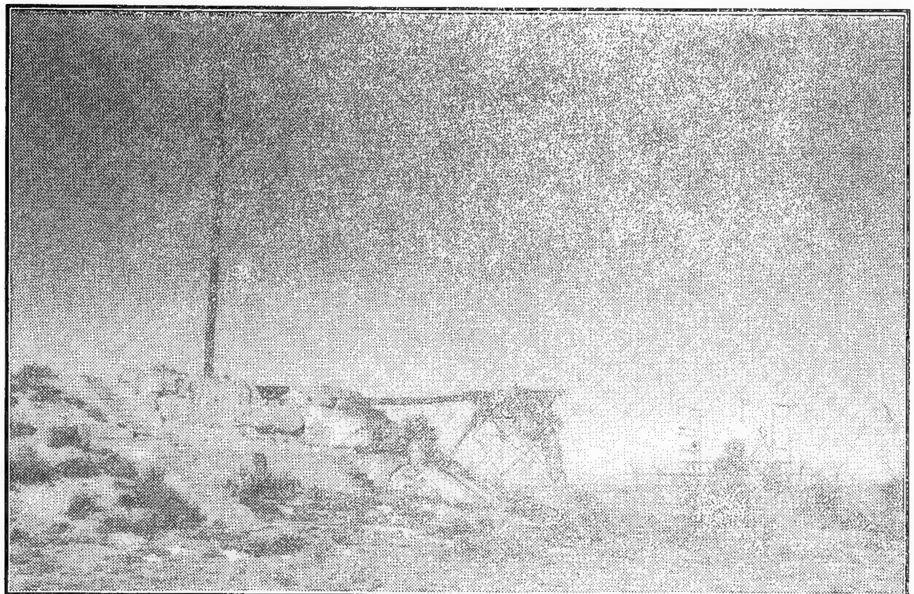


Figure 26. North end of JB-2 ramp with modifications probably associated with the Falcon program, including the Feature 45 tower and Feature 46 electrical station (Mertens/HAFB 1995).

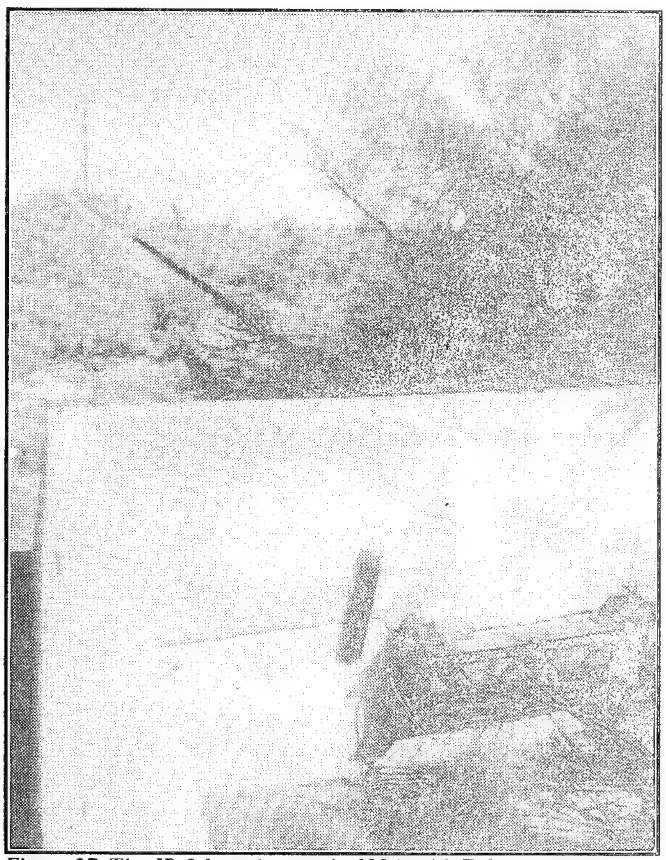


Figure 27. The JB-2 launch ramp in 1994, with Falcon program modification of the loading pit (Allred/Space Center 1994).

Aerobee Rocket

The Aerobee Rocket complex is located just west of the Tula Peak Road approximately 1,000 feet southwest of the GAPA complex within the MTSA (see Figure 4). Aerobee testing was conducted at HAFB between 1949 and 1959, making it the longest-lived rocket development program carried out on the base.

Historical Background

The Aerobee rocket program was conceived in January 1946 and the contract for the project was awarded to Aerojet and signed on 22 July 1946. The objective of the Aerobee program was to develop an upper-air research vehicle-sounding rocket with satisfactory parachute recovery systems for both the nose cone and the main body.

The initial upper atmosphere research programs used captured German V-2 rockets. However, the number of these vehicles was limited, and once exhausted, there was no source of resupply. The V-2 limitations also were well known as a result of the program. The existent WAC (Without Attitude Control) Corporal, an early army rocket, was inadequate too. It was too small to accommodate the expanding field of high-altitude and exo-atmospheric research.

Accordingly, scientists from the Applied Physics Laboratory (APL) of the Johns Hopkins University suggested to scientist James Van Allen that he examine the limited sounding rocket options available for research and submit his conclusions in writing. The reason for this was that Van Allen, a man of political influence, would see that few, if any, vehicles were suitable and would pursue the matter with the objective of obtaining funding for a dedicated research rocket. Van Allen did exactly what was hoped. He concluded that no fully satisfactory sounding rocket existed. He further recommended that the APL act as an agent for the Navy Bureau of Ordnance in the development and procurement of new scientific sounding rockets.

While conducting his survey, Van Allen was introduced to an individual from Aerojet Engineering Corporation. At that time, both Aerojet and Douglas Aircraft Company were manufacturing the WAC Corporal. Then, when tentative approval was granted by the Navy on 15 January 1946, Van Allen contacted Aerojet and requested a detailed proposal for the delivery of 20 sounding rockets capable of carrying a 150-pound payload to at least an altitude of 200,000 feet. After a conference with APL representatives on 2 February 1946, Aerojet submitted a proposal on 22 February 1946. This proposition was titled "Proposal to Develop Sounding Rockets Capable of Attaining Altitudes in Excess of 600,000 Feet and Carry a Payload from 300 to 1,500 pounds, to Include Liquid Rocket Motor and Fuel Development and also to Develop Efficient High Thrust Launching Rockets."

Shortly after the release of this document, the Naval Research Laboratory (NRL) was consulted. This led to Van Allen's recommendation on 1 March 1946 that the Navy Bureau of Ordnance negotiate a contract with Aerojet for the procurement of 20 liquid-propellant sounding rockets. Fifteen of these

were to be for APL, and five for NRL.

On 17 May 1946, a contract was presented to Aerojet. It called for 20 XSAR-1, or Aerobee, sounding rockets capable of delivering a 150-pound payload to an altitude of 300,000 feet. Simultaneously, APL was assigned the task of technical direction for the Navy and Van Allen was appointed director of the Aerobee program. An engineering team was assembled for the new Aerobee effort. This team consisted of Aerojet Engineering serving as the prime contractor and Douglas Aircraft Company performing aerodynamic engineering and some of the manufacturing. [74]

The original design of the Aerobee called for a vehicle about 19 feet long with a gross weight of approximately 1,600 pounds. The engine was to use a mixture of furfural alcohol/aniline and red fuming nitric acid (RFNA) and have a six-foot-long solid propellant booster for initial launch acceleration.

During the period when the rocket was still under construction, a dummy Aerobee was transported to White Sands Proving Ground for flight testing. This dummy vehicle was attached to a live booster and was launched on 25 September 1947. The first firing of a complete rocket took place two months later on 24 November 1947.

Unfortunately, the first firing was not completely successful. At launch plus 35 seconds, the flight was terminated due to excessive yaw, or side-to-side oscillations of the rocket tail. A series of repairs followed, requiring nearly four months to complete. Finally, on 5 March 1948, the second Aerobee was launched and was a complete success. This vehicle reached an altitude of 73 miles (approximately 385,000 feet). [75] Further flight tests followed, including several under the auspices of the Navy and the Army Signal Corps. Finally, on 2 December 1949, the first Air Force Aerobee was launched from HAFB, New Mexico (Figure 28).

Air Force Aerobees were originally ordered under the X-8 designator and were referred to as Project MX-1011. This project was controlled by the Air Research and Development Command and handled by crews from HAFB. [76] The X-8 was a single-stage, unguided, spin-stabilized, liquid-propellant rocket with a solid fuel booster. The main body of the rocket was a conically-tipped metal cylinder with a 15" maximum diameter, and three equally-spaced fins at the aft end. It had no movable surfaces or internal controls. The standard vehicle consisted of a payload section with experiment package, a parachute recovery system, a sustainer unit (liquid fuel rocket section), stabilizing fins, a booster unit with fins, and a booster unit exhaust nozzle. All instruments were installed in the pressurized nose section with the exception of very small objects, which were placed in the tail section. The nose cone provided 4.8 cubic feet of instrument space. The compartment was tapered and measured 87" in length and had a maximum diameter of 15". An additional 1.5 cubic feet of instrument space could be provided by use of a 15" long cylindrical nose cone extension, which was also pressurized.

Normally, the X-8 was launched from a 143 foot tall tower elevated to an angle of 87 degrees. The solid-fuel booster accelerated the rocket to ignition speed in approximately 1,000 feet with a burn time of 2.5 seconds. At that altitude, the booster was jettisoned and the X-8 continued on the mission using the main propulsion engine. The Aerobee rocket usually reached its maximum velocity of 3,600 mph

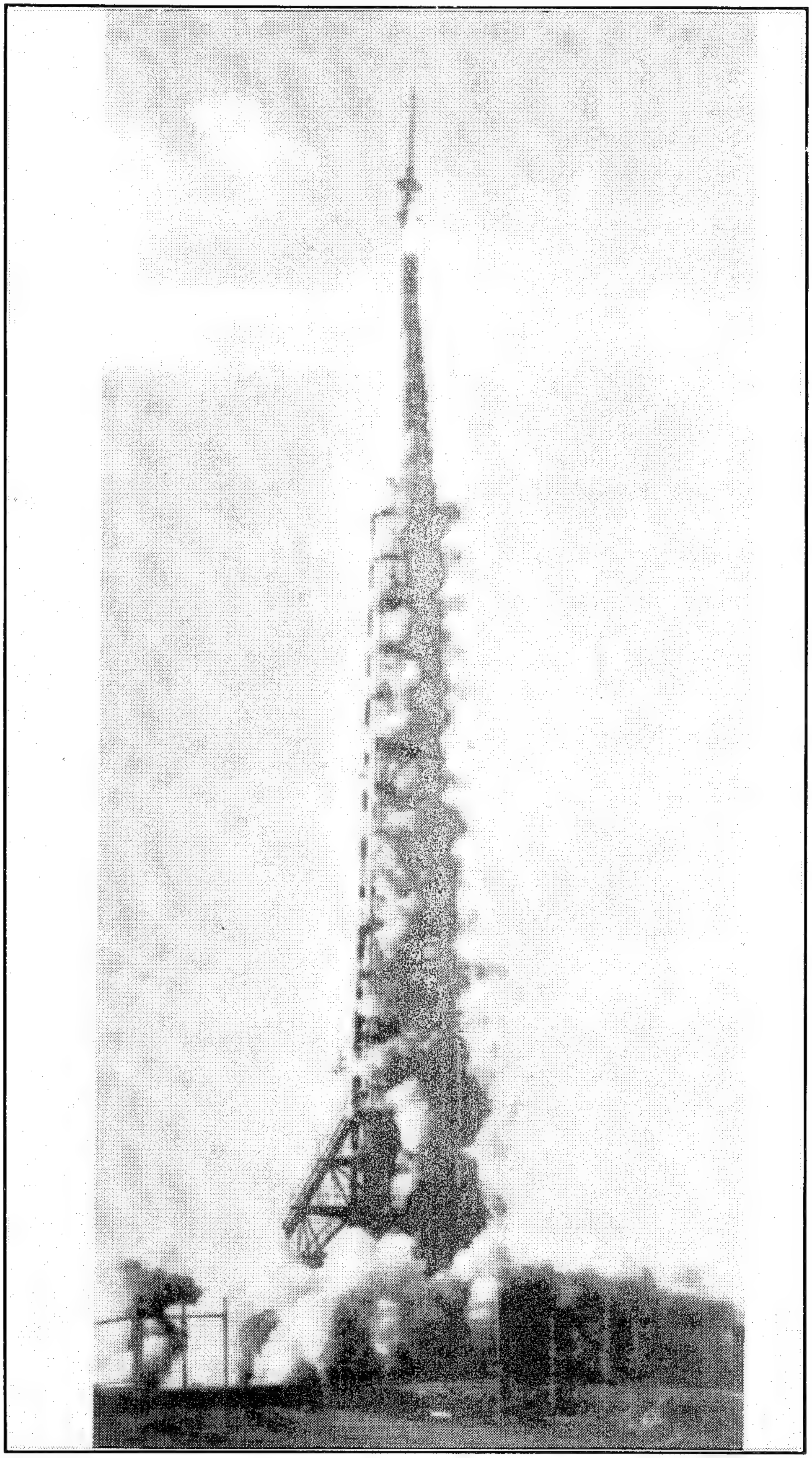


Figure 28. First Aerobee launch from the MTSA at HAFB, 2 December 1949 (Space Center archives).

about 33 seconds after launch. Recovery sequence was initiated at about 200,000 feet when the Aerobee fins were blown off, causing the rocket to tumble. The nose cone with the payload tumbled to about 20,000 feet, where it was blown off the body of the rocket, and the parachute was deployed for the purpose of a soft landing.

According to the Air Force press release covering the event, the first Air Force Aerobee was launched from a nearly 60 foot tall tower at HAFB in the area now known as the Missile Test Stands Area (Figure 29). Launch of this Aerobee was accomplished by Major Phillip C. Calhoun, the Aerobee Project Officer. Radar tracking crews and the recovery crew were following the countdown by radio and were ready for the launch. At 3:20 p.m. the button was pushed and the first Air Force Aerobee roared skyward, reaching an altitude of almost 60 miles (315,000 feet) (see Figure 28). After this historic launch, the rocket remained in the air for 15 minutes and impacted at 3:35 p.m. The impact point was plotted as approximately 20 miles north of the launch site in the vicinity of Tularosa Peak. [77]

This launch was also significant because cameras attached to the rocket took the first color motion pictures of the earth's surface. The payload also included cameras which took black and white motion pictures, as well as X-ray film to study high altitude radiation. [78] Unfortunately, while the payload could have yielded interesting data, it was not retrieved. The nose of Air Force Aerobee No. 1 separated as scheduled and the parachute opened. However, it was not found until 13 July 1950, seven months after the flight. Due to the time delay in recovery, the aerial photographs and X-ray film emulsions were useless. [79]

The first Aerobee launch at HAFB was attended by many dignitaries and members of the press corps. The successful launch resulted in 'positive publicity' for the Air Force. Fortunately, the first

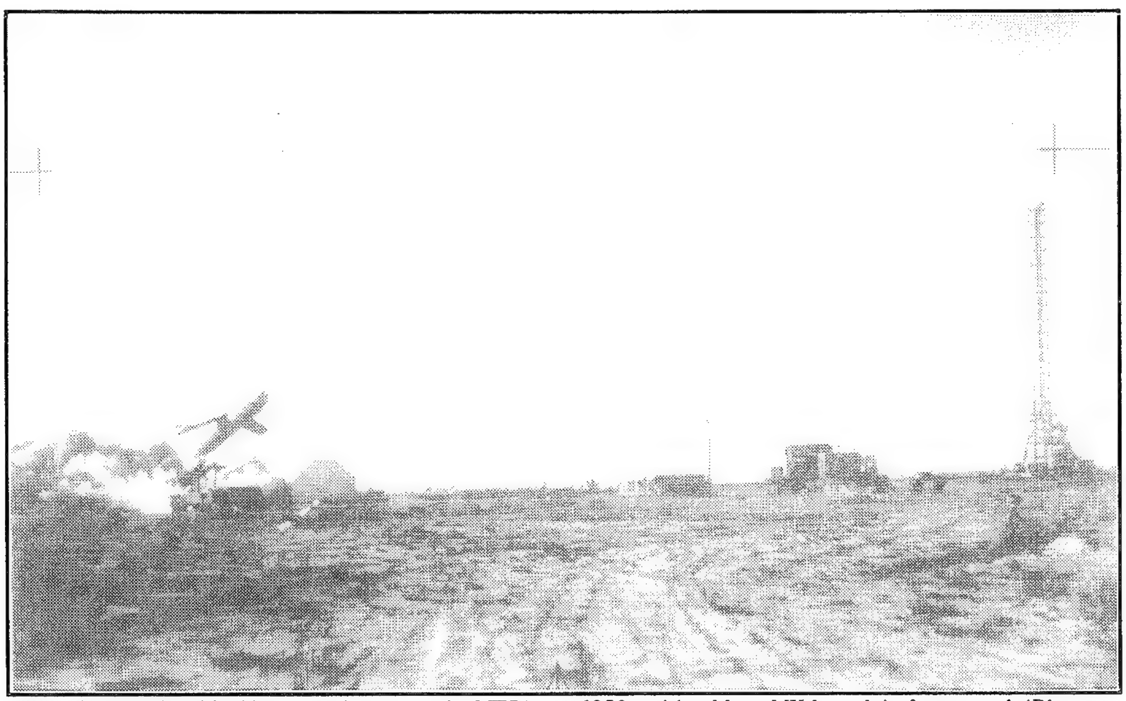


Figure 29. Aerobee blockhouse and tower at the MTSA, ca. 1958, with a Mace MX launch in foreground (Photo courtesy of Andrew B. D'Elasna).

launch went well, because the second Air Force launch of an Aerobee was less than successful. Air Force Aerobee No. 2 was launched at 10:10 a.m. on 15 December 1949, and carried a payload for the University of Michigan. This payload consisted of thermionic ionization gauges and two alphatron gauges. No data was received from this mission because the rocket exploded after leaving the tower. The nose cone was later found about 1,000 feet from the launch tower. [80]

Between December 1949 and December 1952, the Air Force launched 33 X-8/Aerobee rockets from HAFB (Figure 30). The majority of these launches were successful. There were only four failures, two of which never left the launch pad. Altitudes for the successful launches reached as high as 70 miles. Payloads included photographic, solar radiation, biomedical, and atmospheric measurements. [81] Among the flights conducted for biomedical purposes were three carrying monkeys as passengers. Flights with animal passengers had previously been made using German V-2 rockets, but none of these were successful. The first Aerobee flight with a monkey was made on 18 April 1951. The monkey was instrumented and a recording was made of its respiration rate and heartbeat. The data indicated the monkey exhibited no disturbances due to the flight into space. Recovery, however, was not accomplished because the recovery system failed. The second flight was on 20 September 1951, and that Aerobee carried a monkey and eleven mice. Once again the monkey was instrumented and the data showed no abnormalities. The rocket reached an altitude of 236,000 feet (44 miles) and the mission was a success. The nose cone was recovered, but due to the delay in recovery, the monkey and two mice soon died of heat prostration. The third biomedical Aerobee launch was on 21 May 1952, when two monkeys and two mice were sent into space. This mission also was a complete success, including recovery of the passengers. [82]

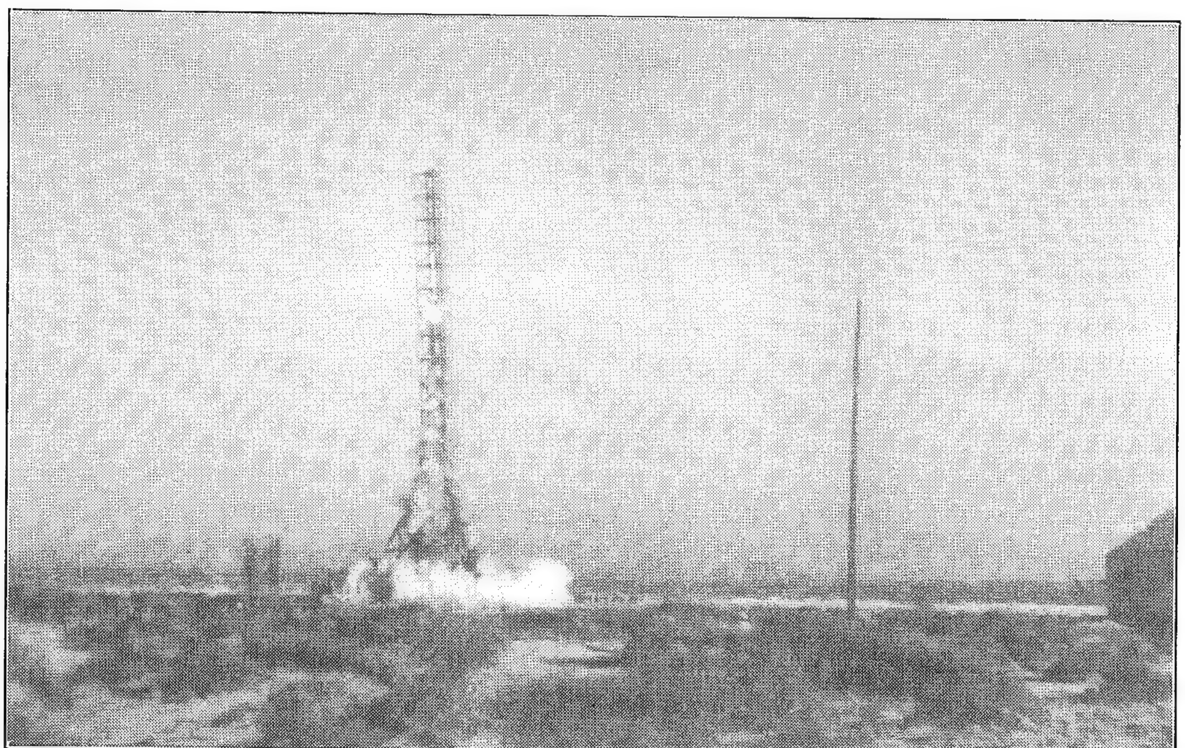


Figure 30. Aerobee launch from tower at MTSA on HAFB, ca. 1950 (Space Center archives).

The mice on these Aerobee flights were studied photographically for subgravity reactions, as well as for being cosmic radiation subjects. One mouse had the vestibular apparatus of the inner ear removed. That is the portion of the ear responsive to gravitational forces which gives mice and humans a sense of equilibrium. This mouse was used to orienting himself by touch and sight and had no problems in space. One of the normal mice exhibited no problems as it retained its tactile sense, as well as visual references, by clinging to a paddle. Those mice that did not cling to anything showed signs of disorientation. [83]

By the end of July 1954, HAFB had seen its 48th Aerobee launch. The press release that accompanied this mission stated the launch was accomplished by the 6580th Test Group commanded by Lt. Col. Harry Boone. The Aerobee was said to be 26 feet long. Since the Aerobee-Hi, which later became the Aerobee 150, had not yet been delivered to the Air Force and the standard length of the X-8/Aerobee was slightly over 20 feet, the length specified must have included the solid fuel booster. The press release further stated the launch was from a special tower located in HAFB's North Area (MTSA). This tower was 142 feet tall with a permanent tilt of one degree toward the north for directional aim. It could also be tilted through an arc of two degrees to the west and one degree to the east to allow compensation for earth's rotation and wind effects.

Final missile checks and a dry run were conducted the day prior to the launch. Missions were usually scheduled for the early morning hours due to wind factors. The crew started the countdown eight hours prior to the scheduled launch time. One hour before launch all checks were completed and the missile was raised to firing position in the tower. The missile was guided by rails until it left the tower. During the launch phase, all spectators were required to be in the authorized viewing area and the crew was in the blockhouse for safety reasons. The 48th launch was successful. [84]

Almost two months after the 48th launch, there was an Open House at HAFB for about 150 members of the Mescalero Apache Indian Tribe. This was truly an "Arrows to Rockets" type of meeting since the visitors included Willie Magoosh, who had ridden with Geronimo (Figure 31). [85]

Launch missions naturally resulted in changes to the rocket and the X-8 soon became the X-8A with increased internal tankage for additional fuel. The X-8A was further modified with still more internal fuel and an updated booster and became the X-8B. Additional changes resulted in the X-8C and X-8D. Aerojet soon introduced the Aerobee-Hi and, later, the further improved Aerobee 150.

The Aerobee-Hi program, known as Project MX-1961 by the Air Force, was developed in response to requests for improved performance of the rocket. A contract was signed in January 1953 and the first Air Force Aerobee-Hi was launched on 21 April 1955. [86] It reached an altitude of 123 miles with a 215 pound payload. The performance of the Aerobee-Hi was boosted by use of longer propellant tanks and superior materials for better weight efficiency. When NASA began Aerobee launches in 1959, it changed the name from Aerobee-Hi to Aerobee 150. The original Aerobee 150 rocket had three fins, but modification to a four-fin configuration resulted in the rocket being renamed the Aerobee 150A. [87] There was not much difference between the booster used for the standard Aerobee and the Aerobee-Hi. Both


Figure 31. Willie Magoosh, last surviving brave who rode with Geronimo, at Aerobee Tower in Sept 1954 (Photo courtesy of the Rio Grande Historical Collections, NMSU Library).

Table 6
Aerobee and Aerobee-Hi Specifications

Standard Aerobee		Aerobee-Hi
256"	Length	278.5"
623 lbs	Propellant Weight	1,054 lbs
4,100 lbs	Thrust	4,100 lbs
32.1 seconds	Motor Duration	51.4 seconds

developed a thrust of 18,000 pounds for 2.5 seconds. Table 6 reflects some of the technical differences between the standard Aerobee and the Aerobee-Hi. [88] With the additional fuel and longer motor burn time, the Aerobee-Hi was able to reach a higher altitude. Maximum altitude for the standard Aerobee X-8 was 360,000 feet (68.2 miles), while the Aerobee-Hi could reach 800,000 feet (151.5 miles). [89]

In one of the early HAFB facilities guides intended for prospective Air Force customers, the following capabilities were listed for the Aerobee: HAFB would furnish the rocket, launcher, launch crew, blockhouse, and beacon used for recoverable packages, while the user was responsible for the instrumentation package. However, the user was limited to 6.25 cubic feet of usable space for the payload. Payload weight and altitude could be traded. A heavier payload of 300 pounds would reach 65 miles, while a lighter payload of 100 pounds would reach an altitude of 85 miles. [90]

The launch tower, by this time, had been extended beyond the 'nearly 60 feet' listed in the 1949 press release. The tower was now 152 feet in height with the final 40-foot addition completed on 20 February 1951. This extension was added because it was deemed "necessary to stabilize the boosterless Aerobee rockets." [91]

Other tests were accomplished by the launch crews using Aerobee rockets. Among these was the placing, on 15 October 1955, of the first sodium vapor cloud in the exo-atmosphere at an altitude of 70 miles and firing artificial meteors from a night-launched Aerobee on 16 October 1957. [92] These meteors traveled at 33,000 mph, which is 8,000 mph faster than escape velocity, and were the first man-made objects to escape earth's gravity. [93] The Aerobee itself, No. 88 in the series, did not escape earth's gravitational field. The artificial meteors that did escape were released by a special explosive charge at an altitude of 58 miles. After release, the meteors were tracked by the Mount Palomar Observatory in California. Some of the meteors went into elliptical orbit around the sun and eventually burned up when they got closer to the sun. [94]

The 100th launch of an Aerobee was on 12 March 1959. This was a test of a Biaxial Pointing Control and reached an altitude of 140 miles. Finally, on 21 June 1959, a pair of Aerobees were launched, marking the end of Aerobee testing at HAFB. [95] Shortly after these launches the Aerobee launch tower was dismantled and moved to WSMR.

Archaeological Perspective

The Aerobee Launch complex consists of an intact control house, firing apron, and 15 non-contiguous features in an 800' x 400' area (Figure 32). An October 1948 Plot Plan for the Aerobee facility shows the control house and firing apron connected by a cable trench, a septic tank, and a transformer vault. Two additional firing aprons are illustrated as "future pad not in contract," but these were apparently never constructed. [96]

The control house, or observation shelter (Building 1142/Feature 133/'Baker 3') is a steel-reinforced cast concrete, two-room subrectangular structure (Figure 33). The 1,087 SF structure has overall dimensions of 38' x 32' 6", and was completed in 1950. The main observation room is 24' 6" x 32' 6" with 2' thick walls and a high truncated hip roof. Three sets of four square, inset windows with 2-3/32" thick bulletproof glass face west towards the firing apron, northwest, and north. These are pocked with bullet holes. Two hung steel doors open onto a concrete sidewalk to the south and east. A steel rung ladder ascends up the east wall and roof to an observation deck with a steel pipe railing on the flat rooftop. [97,98,99] Red graffiti has been painted on the west wall.

A rectangular, 23' 6" x 13' 6", utility room adjoins the south blockhouse wall. It has 6" thick walls, a slightly pitched shed roof, two hung steel doors opening onto a concrete patio to the east, and an aluminum 'garage' door opening onto a concrete pad to the west. The door is badly bent. One door provides access to a latrine. An evaporative cooler is attached to the rooftop. [100]

A 5' square concrete pull box sitting adjacent to the blockhouse provides the beginning of a 2' wide,

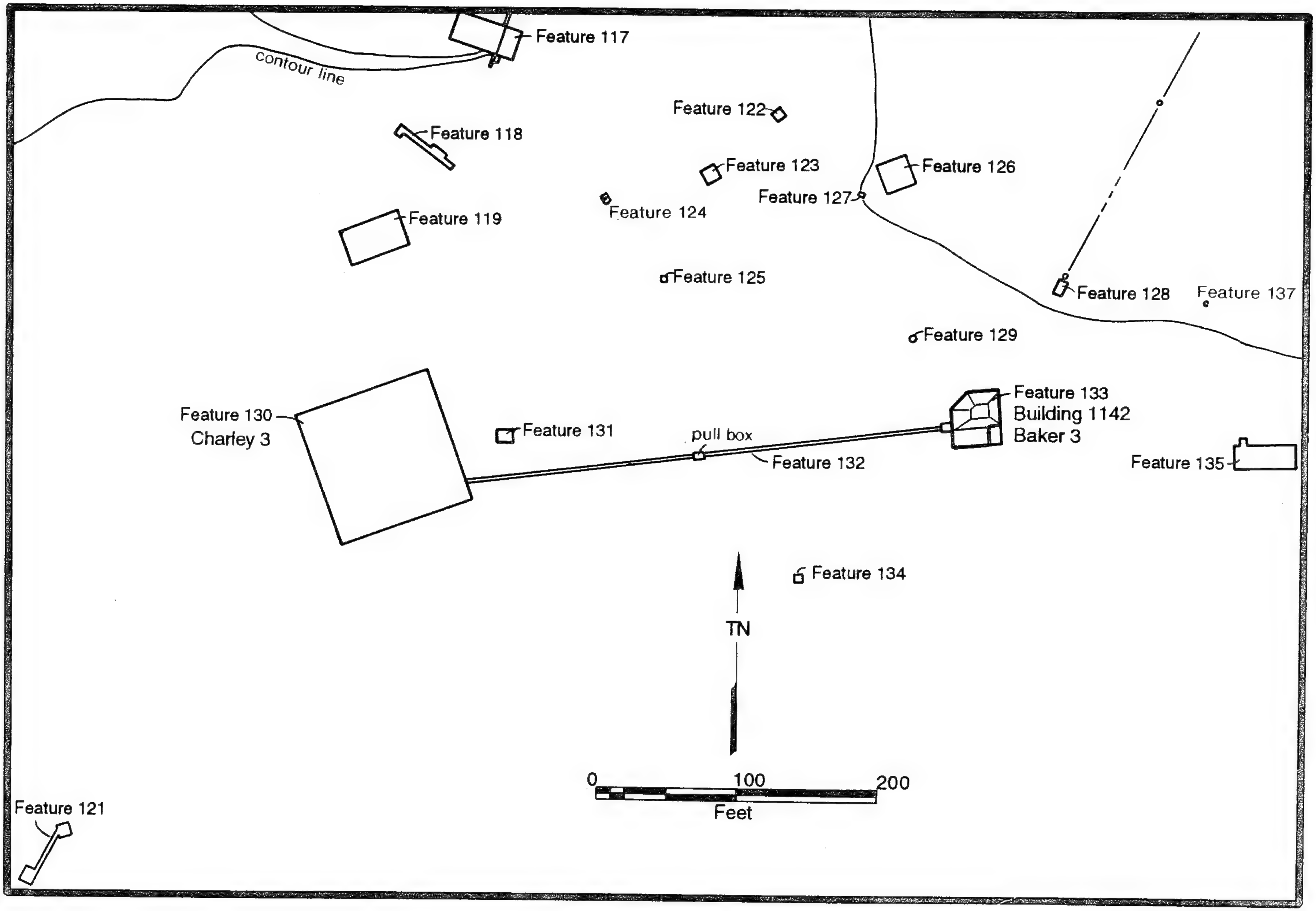


Figure 32. Aerobee launch complex map (adapted from Eidenbach and Wessel 1995).

2' deep concrete cable trench (Feature 132) which runs 340 feet west to the firing apron (Feature 130/ 'Charley 3'). A concrete pull box is situated along the trench. The firing apron is a 100' square concrete pad with a 10' x 4' x 7' steel shed over a 3' 6" x 10' x 3' vault (the terminus of the cable trench), a 14' square x 3' block with a vault and two rectangular footings, and a 5' 8" x 4' x 5' vault (Figure 34). The steel shed is full of bullet holes. The firing apron once supported the steel launch tower illustrated as 112' tall in the 1948 plans. [101] A 12' x 8' x 10' thick concrete pad (Feature 131) with iron tie-downs, is just east of the apron.

Feature 134 is a 2' 6" x 3' 6" vault with a water valve for a deluge system. Feature 128 is the transformer vault. It is a 10' x 6' 6" x 5' concrete vault with a tarpaper roof and four bent steel manhole steps descending into it. The vault is surrounded by a chainlink fence, and a power line runs from the feature towards the NATIV complex to the northeast. Feature 129 is a 3' 3" diameter concrete manhole cover with "WATER SUPPLY AIR-O-BEE" [sic] inscribed on it.

A second series of features may represent one of the additional ramps planned for future construction or another launch complex. Feature 117 is a 47' 6" x 20' x 16' concrete structure extending into an erosional channel (Figure 35). The platform, at ground level, consists of two concrete pads covering a two-room vault. A manhole provides access to the vault, and steel manhole steps descend the wall between the rooms. A small doorway is in the wall between the 11' x 7' 3" x 6' rooms. A large quantity of trash has been deposited in the room below the manhole. Two 10' long wing walls flank the platform and may act as containment walls. Numerous iron plates and conduit sleeves are in the platform, and "WDN 4/11/64" and "64 HORST" are inscribed in the western pad. The remains of a metal pipe railing is on the southwest corner of the pad. Metal pipe supports run south from the structure to concrete conduit sleeves set in the channel bank. Two features, 118 and 119, lie just south of the structure. Feature 118 is a 15' x 5' linear concrete pad possibly representing a sidewalk/ walkway. Feature 119 is a 45' x 30' concrete pad with electrical boxes and a concrete vault. A half-circle depression on the pad may have supported a metal track. These features may have been associated with the Martin Matador/Mace project, conducted in the Aerobee complex area. The Figure 29 photo shows a mobile Mace launch in the vicinity of the features, and the Martin "Fire Control Position" (Baker 10)

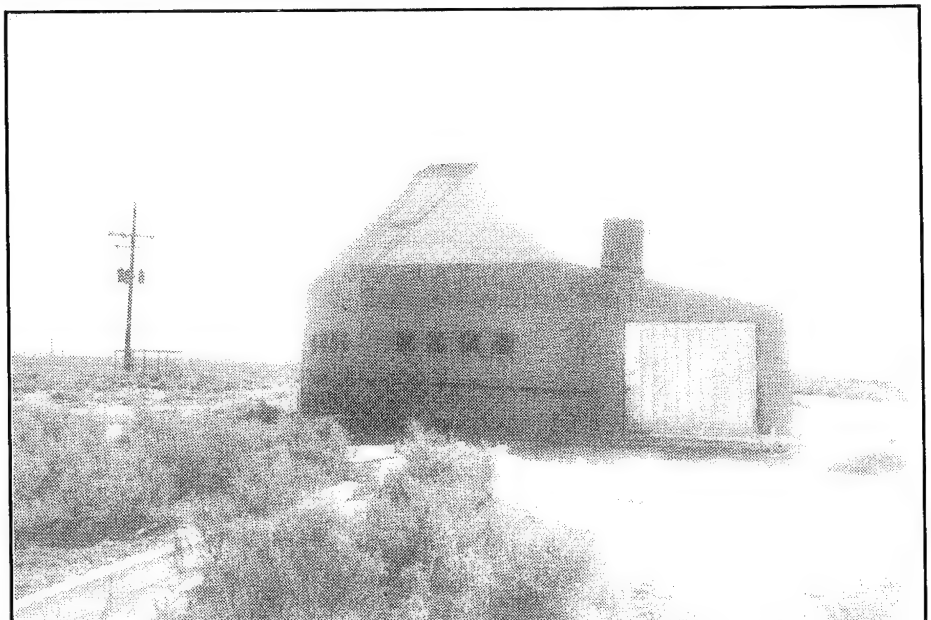


Figure 33. Aerobee observation shelter, west elevation (Allred/Space Center 1994).

is illustrated on an early map as near the Aerobee complex.[102,103]

The base of a rocket in the nearby GAPA complex, Feature 7, matches the dimensions of a booster from an Aerobee rocket (see Table 3 and Figure 9). This was the only rocket or missile wreckage identified in the MTSA which might have been associated with the numerous launch programs. A second base was noted near the first, but has not been identified. An intact Aerobee X-8 from HAFB's 'Missile Row' is currently curated at the ISHF.

Eight additional features are scattered to the north and east of the Aerobee blockhouse. These are listed in Table 7.

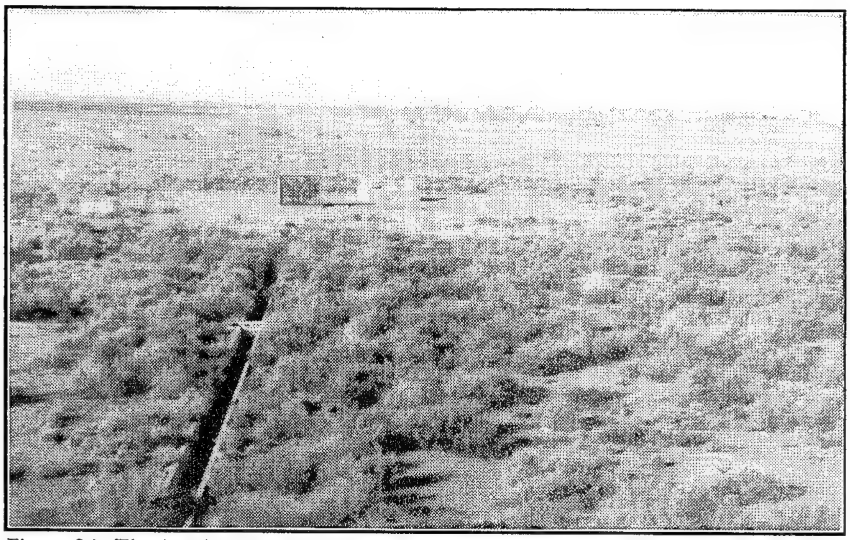


Figure 34. The Aerobee firing apron and cable trench, looking west from the observation shelter (Mertens/HAFB 1995).

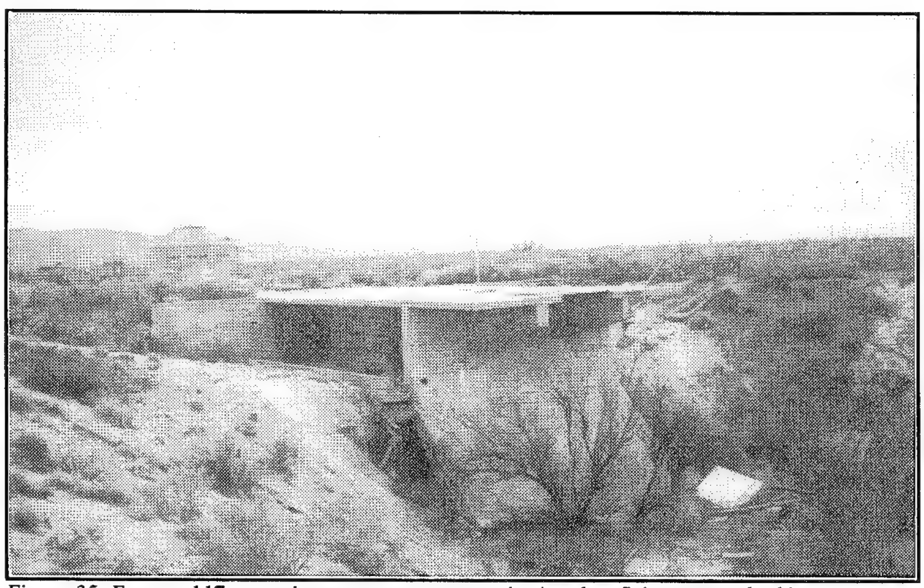


Figure 35. Feature 117, an unknown structure near the Aerobee firing apron, looking east towards the Aerobee observation shelter (Tagg/HAFB 1995).

Table 7
Additional Features within the Aerobee Complex

Feature No.	Description
122	8' square concrete pad with brass cap inscribed with "WHITE SANDS PROVING GROUND TRAVERSE GEODETIC CONTROL F.D.L. STATION T.S. 115 1956."
123	9' square concrete pad with brass cap inscribed with "WHITE SANDS PROVING GROUND TRAVERSE GEODETIC CONTROL F.D.L. STATION T.S.52."
124	Recent 1' square concrete block around brass cap inscribed with "WHITE SANDS PROVING GROUND TRAVERSE GEODETIC CONTROL F.D.L. STATION T.S. 242 1958."
125	4' x 2' 6" x 2' 8" concrete vault.
126	21' 4" x 22' 9" concrete pad with six iron plate covers, four sets of four bolts, and two conduit pipes. An uprooted 3' x 2' x 2' 6" concrete pillar lies beside it.
127	2' 4" square x 2' deep concrete vault.
135	50' x 19' concrete pad with 16' x 6' extension.
137	4' 6" tall metal post.

Able 51

The Able 51 complex, also known as the ZEL Site and BQM 34A Drone Launch Site (identified on a sign leading to the site), was documented in 1994 for this project. [104] Located on a flat alluvial plain at an elevation of 4060 feet ASL, the USAF owned complex is situated on WSMR land about 1.5 miles northwest of the HAFB runways (see Figure 4). As with the MTSA, this complex contains the remains of numerous testing programs operated between 1959 and the late 1970s. Mace and Matador missiles and BQM-34A target drones were tested at the facility. In the following discussion, the term 'ZEL Site' is used as a designation only for the two-bay launch building (Building 1442), while 'Able 51' encompasses the entire launch complex.

Historical Background

In the 1950s, before intercontinental ballistic missiles joined the world's arsenal, the principal Cold War threat was manned bombers. To counter these threats, a massive fighter force was required. Fighters needed long runways for takeoff. If one enemy bomber managed to sneak through the defenses of the United States without being spotted, a single nuclear bomb could wipe out an entire fighter force and render the runway useless. To defend against such a scenario, the ZEL site was created on HAFB. ZEL is the acronym for ZEro Length, referring to the launcher associated with the program. The launch building at ZEL site was constructed to withstand the overpressure resulting from an atomic bomb explosion. This would furnish protection to a fighter aircraft parked in this type of structure, provided the bomb was not detonated so the large opening of the building faced ground zero. In the event of the loss of a runway, it would be necessary to get the projected aircraft airborne so they could stop future attacks. [105]

The latter scenario was solved through the use of a technique similar to the catapult used on U.S. Navy ships for years. A launcher was developed which elevated a fighter so the nose was pointed into the air at about a 15 degree angle. The thrust of a rocket motor attached to the planes fuselage, combined with the thrust from the fighter's jet engine, propelled the combat laden aircraft into the air. Initial tests were conducted with unmanned aircraft, followed by use of an F-84 aircraft and a zero length launcher, and finally with an F-100 on a zero length launcher within the ZEL building.

Newspaper reports of the first tests with an unmanned aircraft resulted in an erroneous yet rather humorous report for the general public. The unmanned aircraft was merely a large weight, equal to the weight of an aircraft, with fins attached to resemble the aircraft tail and rudimentary wings to simulate the lifting surface. The purpose of this test was to see if the solid fuel booster could successfully lift the desired weight into the air and clear of the launcher. The booster was fired and the simulated unmanned aircraft cleared the launcher and the launch area and then slid to a halt in a cloud of dust well in front of the ZEL building. The newspaper report stated that "the test was a success and the pilot successfully escaped injury." The pilot should have escaped injury since the individual designated as test pilot, who was to make the first manned launch, was inside the blockhouse. [106]

In August 1959, an F-100 with a 130,000 pound thrust Astrodyne solid fuel rocket booster strapped to the fuselage was launched from the HAFB ZEL building. The pilot on this first launch was Al Blackburn, a North American Aviation test pilot. Launch was accomplished from a zero length launcher located inside the larger southern ZEL bay. The combination of the booster rocket motor and the jet engine thrust combined to boost the F-100 to a speed of 300 mph and an altitude of 350 feet in just six seconds. This launch was accomplished with landing gear and flaps down. Later, another launch of an F-100 from the ZEL site was successfully conducted, but then the concept apparently lost favor because no further tests were conducted. [107]

The same launch concept was applied to the smaller northern bay of the ZEL site. This bay was equipped with a zero length launcher capable of launching the Mace missile (Figures 36 & 37). The

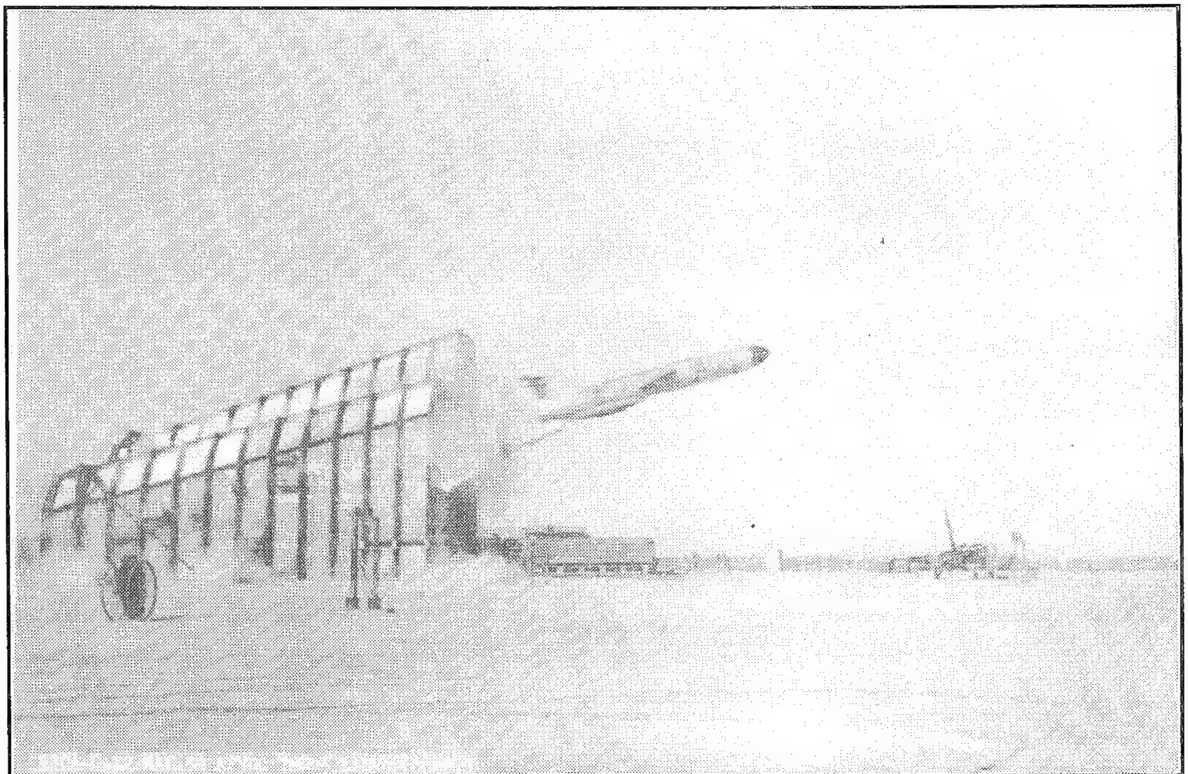


Figure 36. Mace MX launch from Zel site at HAFB, 12 May 1959 (Space Center archives).

launcher was inclined 19 degrees above the horizontal. The Mace missile started out as the Martin B-76, and underwent a nomenclature change to TM-76. The Mace was 44' long, had a wing span of 22' 11", and weighed 18,000 pounds. It was powered by an Allison J33-A-4 jet engine with 5,200 pounds thrust. Launch was accomplished by a combination of the jet engine and a Thiokol solid rocket booster that generated 50,000 pounds of thrust. Guidance for the TM-76A version was furnished by a Goodyear Atran Terrain Comparison system. The TM-76B version had an AC Spark Plug Achiever Inertial system. [108]

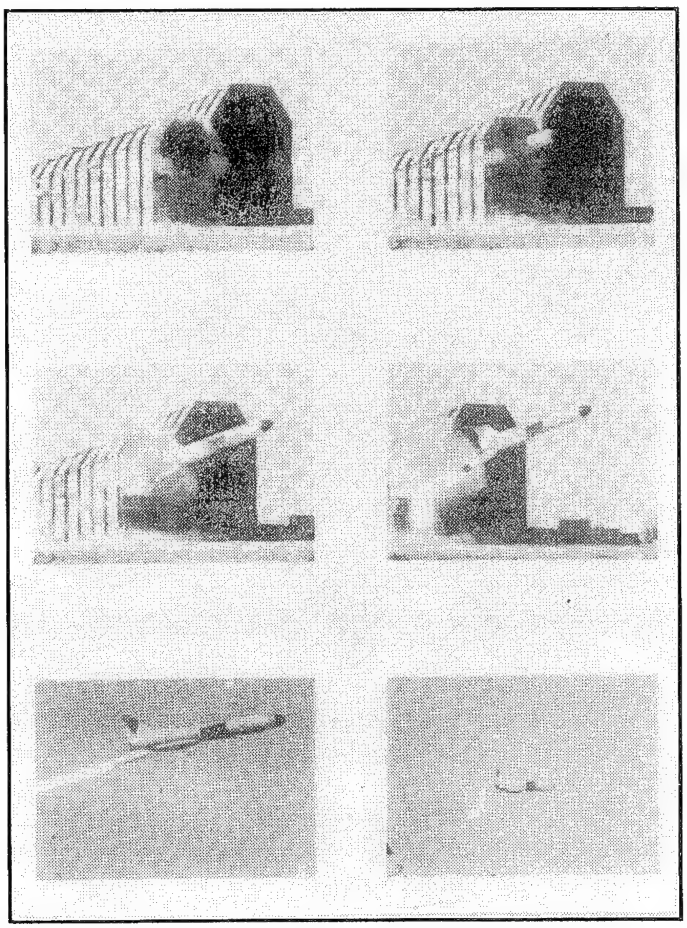


Figure 37. Multiple photo sequence of Mace MX launch from Zel site, ca. 1959 (Photo courtesy of Andrew B. D'Elosua).

Mace missiles were assembled and checked out in Building 1264, a missile assembly building which is currently part of the Primate Research Lab. After assembly, missiles were transported by truck to the ZEL site where they were hoisted onto the launcher and preparations

for flight were completed.[109] One of the flight preparations included attaching a 200 foot long cable to the bottom of the Mace. During the launch phase, this cable would stretch out to its maximum length and then be extracted from the missile, provided the circular locking ring was unscrewed. If the locking ring had not been unscrewed, the cable would break at some undetermined point and, dangling behind the missile, could create a hazard for the chase pilot.[110]

A concrete semi-subterranean blockhouse, no longer in existence, was used as the launch control station for the Mace missile (Figure 38, see Figure 36). Later projects at the ZEL site and Able 51 used Building 1440 for that purpose. The concrete pad just north of this latter building was used to launch the Matador missile, later known as the Martin B-61 or TM-61.[111] The Matador TM-61A was 39' 9" long, weighed 12,000 pounds, and had guidance furnished by MSQ radar. The TM-61B version was 45' 10" long, weighed 13,000 pounds, and used Shanicle Hyperbolic guidance. Wing span for both versions was 28' 10". The Matador was powered by an Allison J33-A-37 jet engine, which produced 4,600 pounds thrust. A Thiokol booster, giving 50,000 pounds of thrust, assisted the Matador during the launch phase.[112]

Fixed launchers were considered vulnerable to enemy attacks, so mobile launchers were developed. Both the Matador and the Mace missiles could be transported and launched from these mobile launching platforms (Figures 39 & 40). The transporter/launching platforms resembled the flatbed trailer portion of a tractor-trailer. A zero length launcher held the missile during the transportation phase, then the front end could be elevated to give a positive angle-of-attack for launch.[113]

After the Matador and Mace missiles became operational, crews would be brought to HAFB for their annual training, which included the launch of a missile. Missiles on the transporter/launcher were

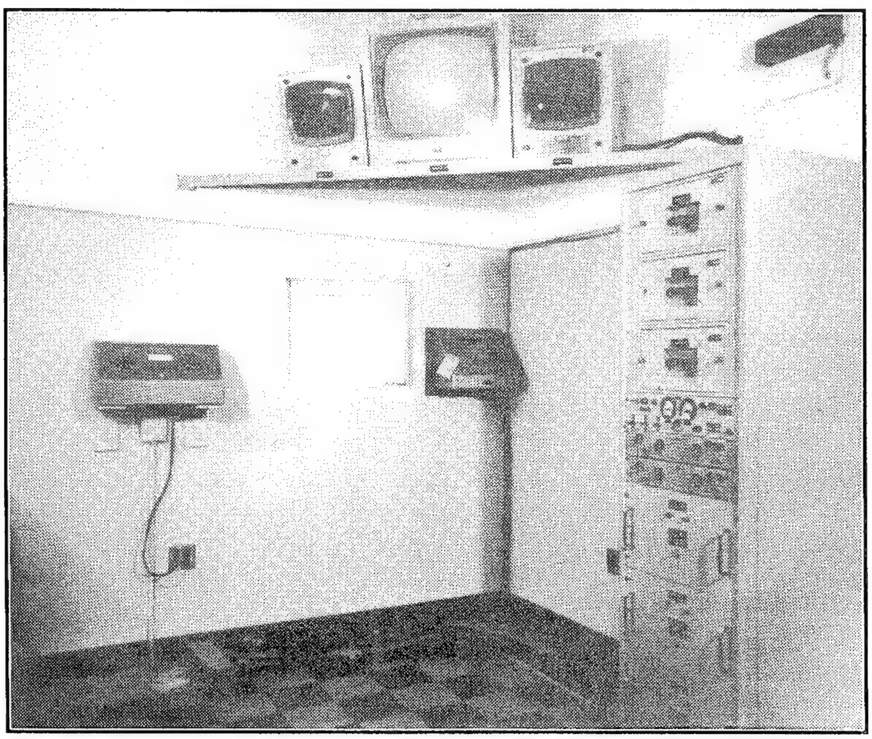


Figure 38. Interior of orginal blockhouse used for launch control of Mace MX, ca. 1959 (Photo courtesy of Andrew B. D'Elosua).

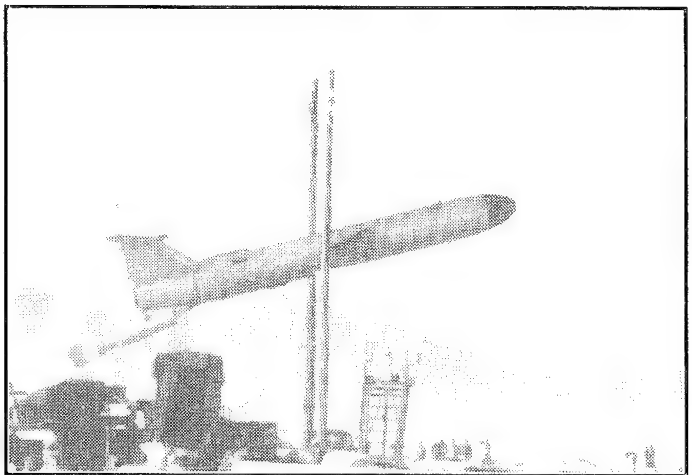


Figure 39. Mace MX launch from a mobile launcher at MTSA on HAFB, ca. 1958. Telephone poles simulate the width of the ZEL bay exit (Photo courtesy of Andrew B. D'Elosua).

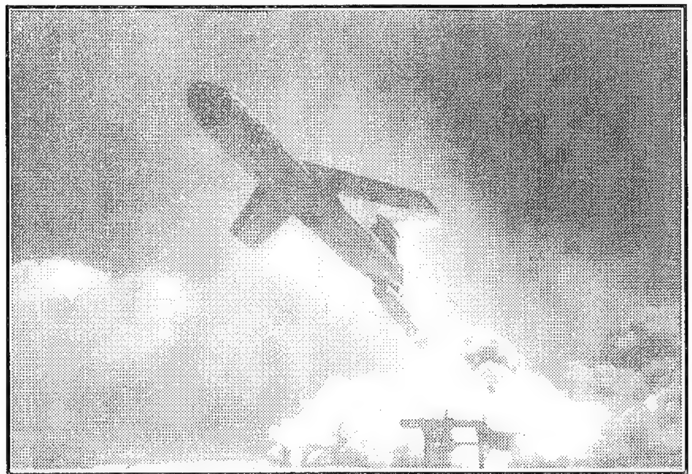


Figure 40. Mace MX launch from a mobile launcher at Able 51, ca. 1958 (Photo courtsey of Andrew B. D'Elosua).

taken to the Matador pad at Able 51, the concrete pad in front of the ZEL building, or to any location the training program might select (Figure 41). The MTSA was apparently one of the locations used for this purpose (see Figures 29 & 39). A later development involving the Mace missile was known as 'Rapid Fire' (Figure 42). Four missiles would be transported to the selected launch site and set up adjacent to each other. They would be controlled from a single locatiön. Even though the annual training exercise called for Mace missiles to be set up in the rapid fire configuration, only one of them would actually be launched. [114]

Missiles launched from the ZEL site were capable of traveling long distances, often going farther than desired. One launch saw the Mace missile disappear beyond WSMR heading north. The local newspaper carried the Air Force story that the "missile had gone off-range and was recovered on a ranch west of Albuquerque." Information obtained from a member of the launch crew indicated the missile flew well past Albuquerque over 207 miles to the north. Chase planes followed the missile until they had to return for fuel. The missile's destruct mechanism failed because, as the postflight incident investigation revealed, the device which initiated the sequence flight termination mechanism had been inadvertently crushed and was inoperative. The missile kept flying until it went into the parachute recovery mode somewhere in Wyoming, where it was recovered by the Air Force. [115]

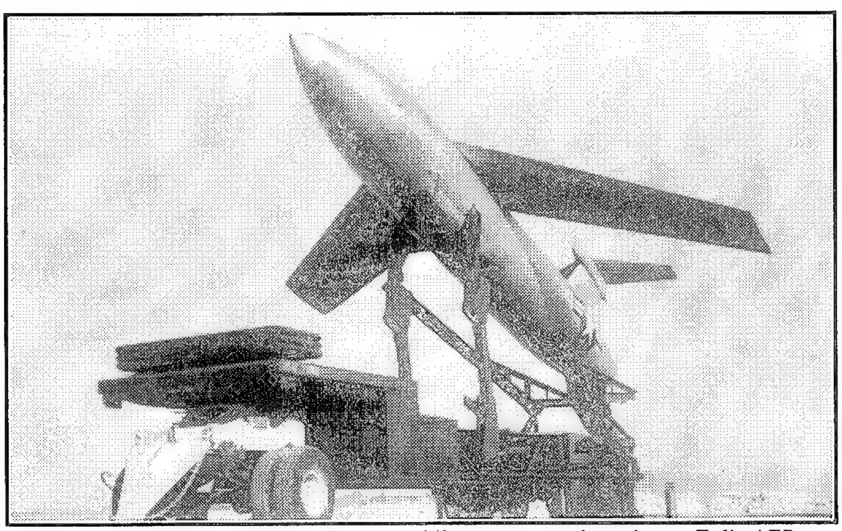


Figure 41. Matador missile launch on a mobile transporter/launcher at Eglin AFB, Florida, ca. 1951 (USAF Photo/Space Center archives).

Other missiles launched from

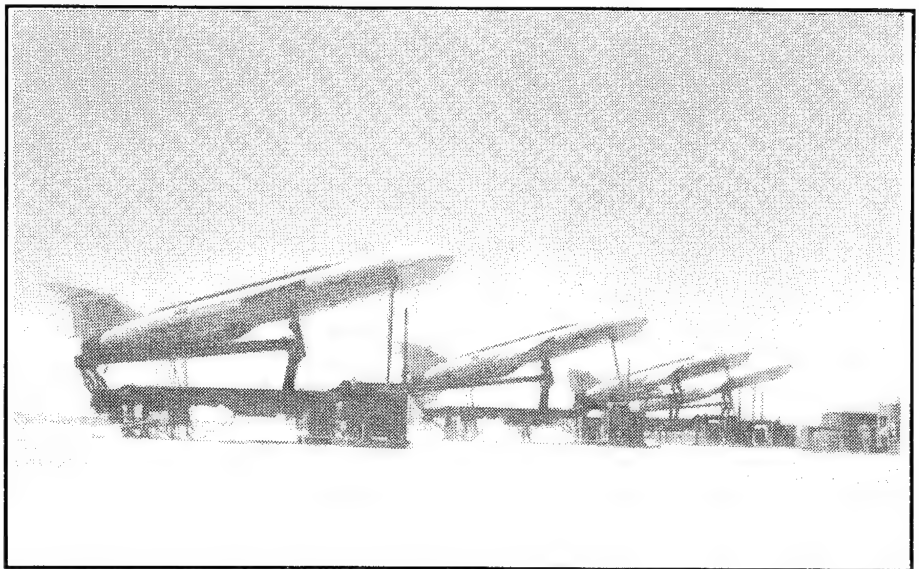


Figure 42. Mace MX arranged in rapid fire configuration at Able 51, ca. 1960 (USAF Photo/ Space Center archives).

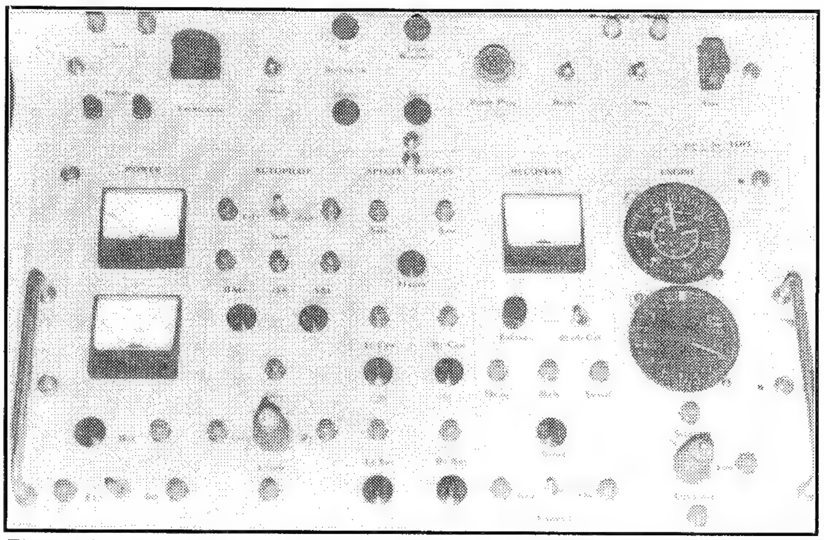


Figure 43. Drone launch control panel in Building 1440 at Able 51, ca. 1971 (Photo courtesy Wayne O. Mattson).

the ZEL site were recovered on the range at Wendover, Utah with no attendant problems. [116] Long-range missions from ZEL to a recovery point in Alaska were planned, but the concept was discarded because there were too many populated areas along the route of flight and the probability of a mishap was considered too high. This high probability resulted in the program being transferred to Cape Canaveral, Florida, where long-range firings were conducted. [117]

After the completion of the test programs and the transition of these missiles to other locations, the Able 51 facility was used as the launch point for BQM-34A target drones (Figure 43). There were two launchers situated on the concrete pads between the Building 1440 blockhouse and the ZEL building. One of these launchers was known as the fixed launcher because it was permanently mounted using bolts set in the concrete (Figure 44). In 1971, when it was determined that the launch azimuth crossed the High Speed Test Track buildings, the launcher was reoriented to preclude mishaps during launch.

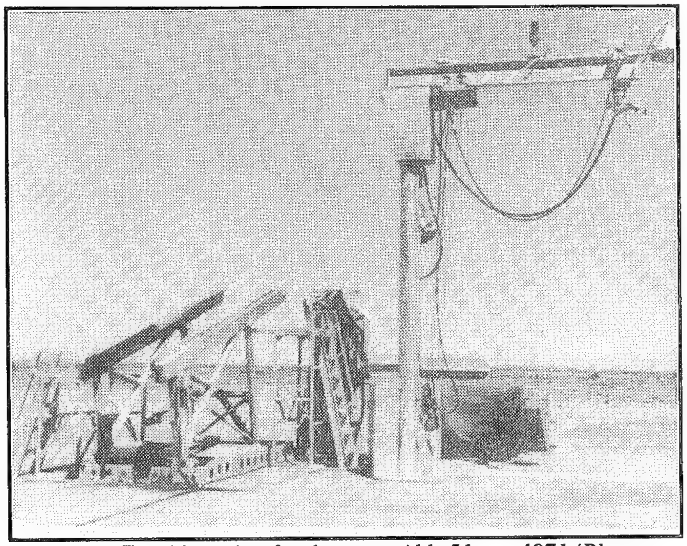


Figure 44. Fixed launcher for drones at Able 51, ca. 1971 (Photo courtesy of Wayne O. Mattson).

The second launcher was known as the Mobile Launcher since it could be towed to any location on HAFB or WSMR and put into operation in a very short period of time (Figure 45). [118]

The BQM-34A drone was built by Teledyne-Ryan Company and was powered by a Continental J69-T29 turbojet engine which produced 1,700 pounds of thrust. The drone was 23 feet long and had a swept back wing with a span of 12' 11". It was 6' 8" tall and weighed approximately 2,500 pounds and was launched using a solid rocket booster in conjunction with the jet engine (Figure 46). The drone, also known as the 'Firebee,' could reach a speed of Mach 0.9 and an altitude of 55,000 feet. After launch, it was remotely controlled from the King-1 control station two miles to the northeast. Recovery of the BQM-34A was accomplished using an 82 feet in diameter parachute. [119]

In the late 1970s the drone function at HAFB was abolished and the use of Able 51 as a test facility ended.

Archaeological Perspective

Able 51 (HAR-075/LA 107799) consists of two intact buildings and 32 features in two loci within a 1,210' x 980' area (Figure 47). Locus A contains the buildings and most features, with Locus B 230 feet to the south. All documented features within this site are discussed below. It is probable that more features are present beyond the boundaries of the area investigated, but only additional inventory can verify this.

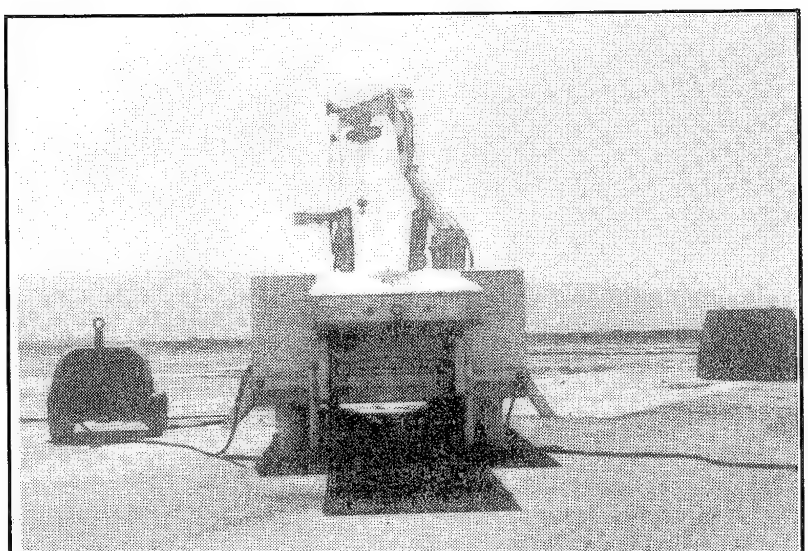


Figure 45. Mobile drone launcher at Able 51, ca. 1971 (Photo courtesy Wayne O. Mattson).

An October 1960 plot plan for the "G/M [guided missile] Launch Facility" shows two launch pads, one labeled "L-102," as well as a "hardsite," two dugouts, and the "new G/M Launch Facility" within the area documented as the Able 51 site. Five additional launch pads, four labeled "RFML L-237" and the other "Owl Launch Pad," are shown between 200 feet and 1,200 feet from the site. [120]

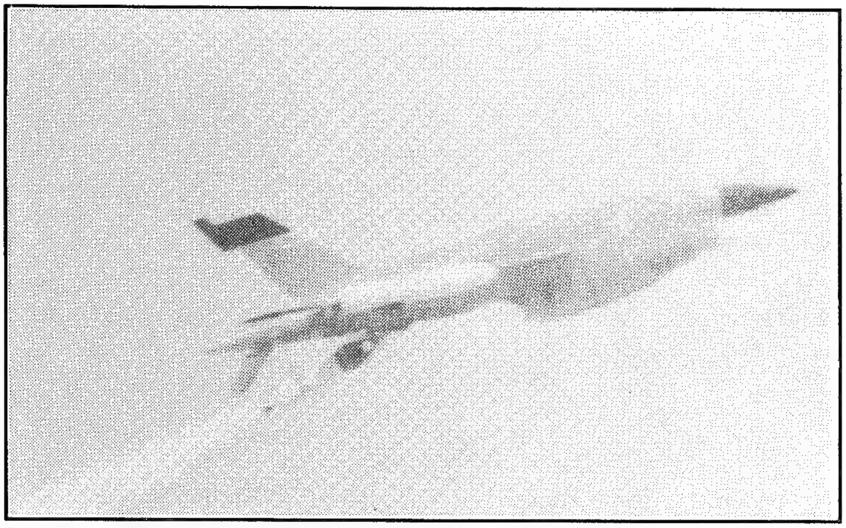


Figure 46. BQM-34A drone during boost phase, ca. 1971 (Photo courtesy Wayne O. Mattson).

The 'hardsite' apparently refers to Building 1442 (Feature 11/Zel site), which was constructed in 1959 as a Missile Launch Facility for the F-100 and Mace missile. The two-bay structure, completed in 1959, is 62' 8" x 74' with 4,638 SF of interior space. It has a concrete foundation and floors and reinforced steel walls and shed roof (Figure 48). [121] The two launch bays open to the northwest. The larger, southern bay where the F-100 was launched, has two steel hung doors and a steel rung latter on the south side. It is fronted by a 76' x 28' concrete pad (Feature 12) with a 14' x 12' extension to the north and a 10' x 38' iron plank/cover and cable trenches in the center. This iron cover was apparently used as a base for a mobile or fixed launch ramp. Concrete footings and iron braces for a blast tube extend 49 feet from the back (east side) of the bay. Two small concrete pads, measuring 5' x 3' and 5' x 8' (Feature 10) are south of the structure.

The smaller bay, used for Mace launches, is fronted by gravel and has two doorways and a ladder on the north wall. Concrete pads, concrete footings, and three pieces of 8' diameter blast tube extend 86 feet out from the back, or east wall. All openings on the building are covered with chainlink fencing to keep intruders out. The interior of the structure is covered with spray painted graffiti probably done prior to installation of the fences and many of the heat tubes have been removed.

A 3' wide asphalt sidewalk (Feature 9) and a 2' wide concrete-lined trench with an iron track in it (Feature 8) run south from Building 1442 to a heavily disturbed 30' x 20' area with large chunks of concrete, rebar, and water pipes (Feature 5). From early photos, Feature 5 was a semi-subterranean concrete blockhouse with a pitched roof and viewing windows at ground level (see Figure 36). It is probably one of the dugouts illustrated on the 1960 plot plan. [122] This building was apparently the control center for Mace and BQM-34A drone launches. It was bulldozed and completely destroyed some time in the past, and the area around the feature has also been impacted.

Building 1440 and three concrete pads, located north of Building 1442 within a 155' x 135' chainlink fence, represent the "G/M Launch Facility." [123] The interior of the fenced area is asphalt and gravel. The one-room structure (Feature 16), completed in 1962 as a Missile Launch Facility, is 15' 6" x 22', with 341 SF of interior space (Figure 49). It has a concrete foundation, tile floors, 8 1/2" thick concrete block walls, and a flat concrete roof. A single hung metal door opens onto a concrete pad to the north and there are 10 rectangular viewing slots (5 in east wall, 1 in north, 2 in west, and 2 in south). The

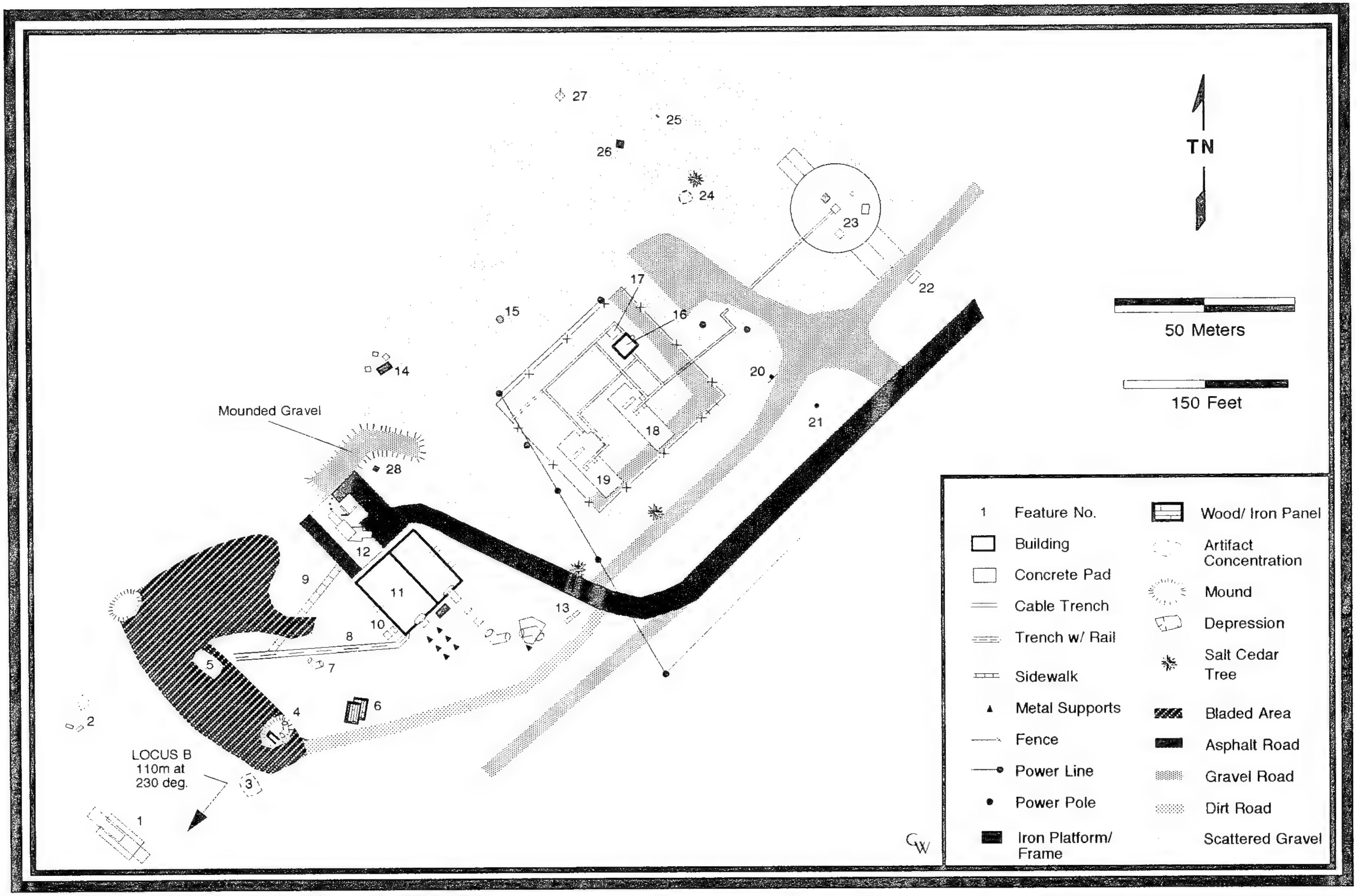


Figure 47. Able 51 (HAR-075/LA 107799) site map.

building was remodeled in 1963, with the front wall extended 4 feet and the concrete pad added. [124,125]

Three concrete pads are also in the enclosure. Feature 17, adjacent to Building 1440, is a 5' 6" x 10' pad with 4 iron tie-down rings and a 4' x 2' 8" extension to the north. Features 18 and 19 are 75' x 20' pads with 12' 6" x 1' 6" vaults and iron tie-down rings in the centers. [126] Feature 18 has an 11' x 6' pad connected to the north. Feature 19 has a 10' x 21' pad to the north and a brass cap inscribed with "DEFENSE MAPPING AGENCY/HAFB 3A/STATION DESIGNATION/YEAR 1986/ORGANIZATION DMA DET 2 ORSS/SURVEY MARK" in one corner. These pads were used as launch points for the BQM-34A drone. Concrete lined, 1' 7" x 1' 6" cable trenches run from Building 1440 to the three pads. Steel, checkered plate covers protect the trenches. What appears to be a buried trench runs south towards Building 1442.

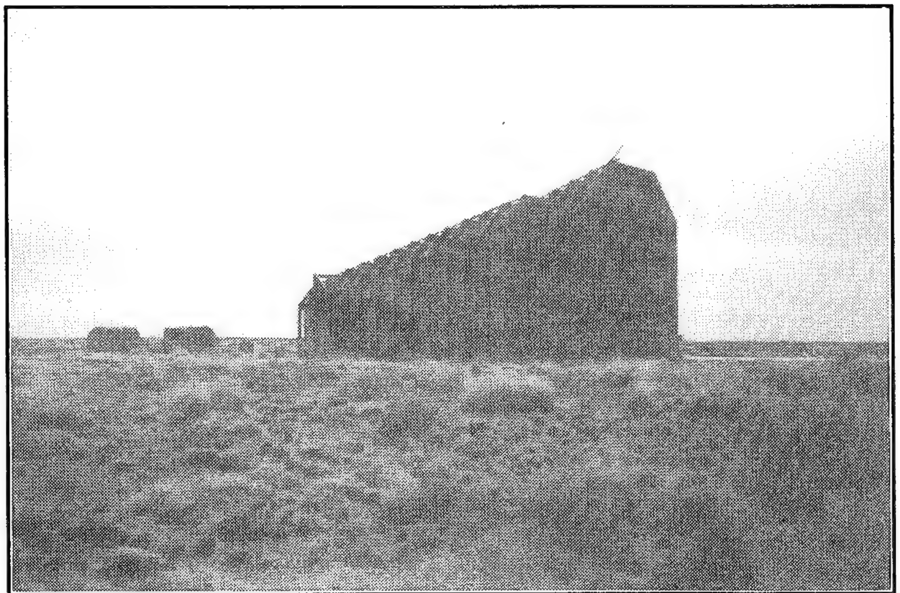


Figure 48. The Zel site, Building 1442, north and east elevations (Tagg/HAFB 1995).

A cable trench also runs north to the Feature 23 concrete pad, representing the "Launch Pad L-102," or the Matador launch pad. [127] The feature is 75' in diameter with a 35' x 31' pad extending to the east and a 22' 6" x 20' pad extending to the west. The cable trench from the guided missile launch facility runs to the center of the pad, terminating in a 4' square vault. A portion of this cable trench has been filled with concrete, and is inscribed with "A1C COM 87." Two other 6' square, concrete covered vaults are in the pad. A 1' 2" square concrete block encasing a brass cap (Feature 32) is just south of the pad. The cap is inscribed with "MATADOR FLIGHT TEST/MARTIN CO/SURVEY MARKER/DO NOT DISTURB/258H0401018-4-1." A dugout illustrated on the 1960 'G/M Launch Facility' plot plan

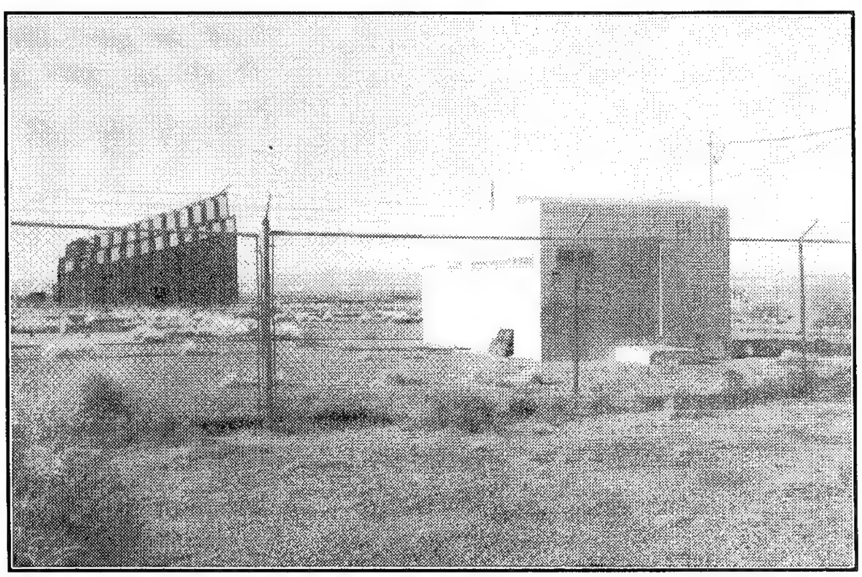


Figure 49. Building 1440, launch control building, north and east elevations, looking towards the Zel site (Mertens/HAFB 1995).

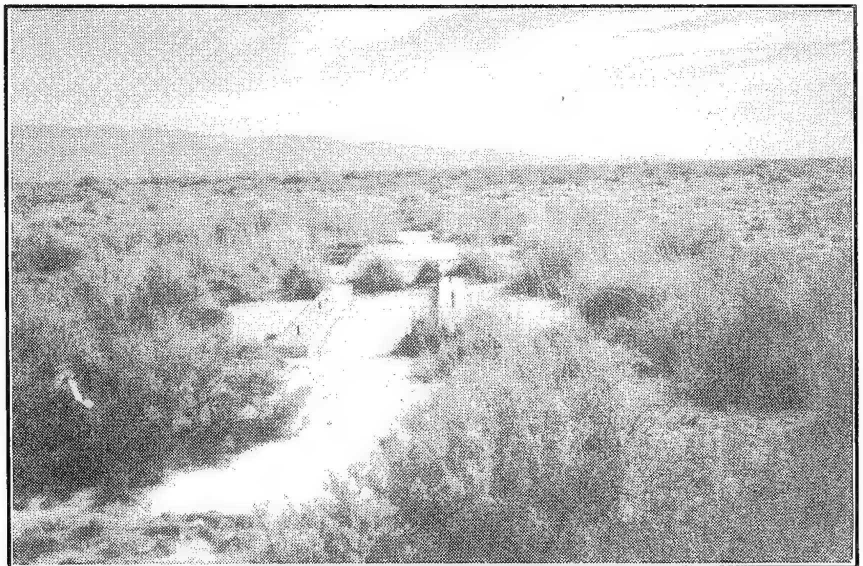


Figure 50. Feature 1 concrete pad, a possible launch facility for early Matador\Mace missiles (Tagg/HAFB 1995).

between the fenced enclosure and Matador launch pad could not be relocated.

Feature 1, possibly the second launch pad illustrated on the 1960 plot plan, is located south of Building 1442 (Figure 50). It is a 66' x 13' 4" concrete pad with a raised, 12' 6" x 5' 4" pad on it. Two, 1' x 24' 6" concrete footings, spaced 3' 4" apart, extend from the raised pad to the west. This feature is labeled "84209" on current HAFB facility maps. It may have been a launch facility for Matador\Mace missiles. The remaining features in this complex are listed in Table 8.

A possible missile or drone wreck was located on a previous survey in a direct line from the bay openings of the ZEL site. The aluminum wreckage was scattered in a large area around the Salt Lakes, 0.6 miles northwest of the launch facility. [128] The wreckage had an aluminum plate inscribed with "CONTINENTAL AVIATION AND ENGINEERING CORPORATION ENGINE-TURBOJET MODEL NO. J-69- . . . SERIAL NO. T-E410053 DATE 2-24-60 MFR. MODEL NO. 356-7A INSPECTED CONTRACT NO. AT-33-600-38080 STOCK NO [BLANK] U.S." The plate is from the engine of a BQM-34A target drone, which was undoubtedly fired from Able 51 and crashed shortly after launch. A Martin TM-61 Matador missile and a Ryan Q-2 Firebee drone from HAFB's Missile Row are currently curated at the ISHF. The Q-2 is listed here because it is similar to the BQM-34A and may have been tested at Able 51.

Table 8
Additional Features within the Able 51 Complex

Feature No.	Description
Locus A	
2	Pile of lumber, concrete, two plywood doors, and metal sheet.
3	Pile of black rubber hose, iron panel, and iron frame.
4	Pile of sandbags, corrugated metal pipe, concrete and metal u-shaped frame with circuit box, and iron frame.
6	Four 18' x 8' wooden wall panels with metal frames.
7	3' diameter metal corrugated pipe.
13	Two 5' 6" x 3' 8" x 4' concrete stands with concave tops for securing pipes. Painted with graffiti.
14	16' x 6' x 5' 6" iron platform, two sheet metal transformer boxes, and yellow metal frame on concrete pad.
15	Iron instrument stand.
20	"Buried Cable" sign.
21	Metal sign post.
22	8' x 4' concrete pad.
24	Pile of poured concrete.
25	2" x 4" wooden post set in the ground.
26	4' x 4' 4" iron frame.
27	Concrete chunk with rebar.
28	4' x 4' 6" iron plate.
Locus B	
29	Two 10' x 7' concrete pads and wooden power pole.
30	26' long, uprooted, concrete foundation with rebar.
31	"Buried Cable" sign.

Horizontal Test Stand

The Horizontal Test Stand (HTS) is located approximately 0.6 mile east of the High Speed Test Track (HSTT) above Hay Draw (see Figure 4). As a support building for the HSTT, the HTS was used primarily for the Atlas Engine Test Program and servicing liquid-fuel sled engines from 1957 to the mid-1970s.

Historical Background

The original 3,550 feet long HSTT was constructed for testing the Snark Missile between June 1950 and March 1952. The track was extended 1,521 feet in 1952, and through 1956 numerous programs utilized the facility for acceleration and impact testing of missile warheads under the project title 'Sleighride,' OQ-19 and Q-2 drone testing, flight control and guidance systems for the OQ-19, MX-1601, and B-58 wing configuration, and a research program into the biophysics of abrupt deceleration. The track was extended to it's current 35,000 feet length with construction starting in 1957, and by 1960, the 1,000th rocket sled reached a speed of 2,660 mph. Support facilities directly associated with the track included five blockhouses, a vehicle assembly and maintenance building, booster conditioning building, fuel storage facilities, administration buildings, and numerous instrumentation stations such as pads for tracking cameras. [129]

As part of the HSTT extension to 35,000 feet, a number of support buildings were envisioned. One of these included the HTS. Even though the extension was formally accepted on 25 February 1959, some of the support buildings were not completed at this time. [130] Two conflicting directives contributed to the creation of the HTS. One of these directives was known as the 'dispersal policy' or the 'California policy.' This directive originated at the highest levels of government and required that future missile development be conducted away from the seacoasts, where there was a concentration of defense airframe and electronics companies. The purpose of the directive was to bring about wider national distribution of missile development and production in order to lessen the vulnerability of these industries to possible enemy attack. [131] Another directive was to hasten the development and production of the Atlas missile. Among the urgently needed facilities were rocket engine test stands and appropriate assembly buildings. The HTS originally was intended for Atlas engine tests. [132]

Project 6888, Test Track Instrumentation, was ordered established in mid-1957 by Headquarters, Air Research and Development Command. After the appropriate paperwork was submitted, the project was approved in February 1958. Part of this project was Task 68880, the horizontal rocket-test stand (HTS). The objective of this task was to obtain instrumentation and other equipment needed to put the HAFB HTS in operating condition. In June 1958 a design study contract was awarded to the Aerojet-General Corporation. Although completion date of this contract was specified as January 1959, the task was disapproved at Command level as unnecessary and inappropriate since it was not devoted entirely to instrumentation. [133]

The structure of the HTS, designed to be capable of withstanding one million pounds of thrust, was completed, but the required instrumentation was never installed. The facility's mission was changed from the Atlas Engine Test Program to servicing liquid-fuel sled engines between runs on the HSTT and for acceptance and calibration testing of solid- or liquid-fuel engines. However, the number of such runs was considerably less than first anticipated. Therefore, the liquid engines were serviced on the track itself and the HTS was placed on standby status, to be activated whenever the need arose. The need did arise later upon the receipt of liquid-fuel rocket engines. [134]

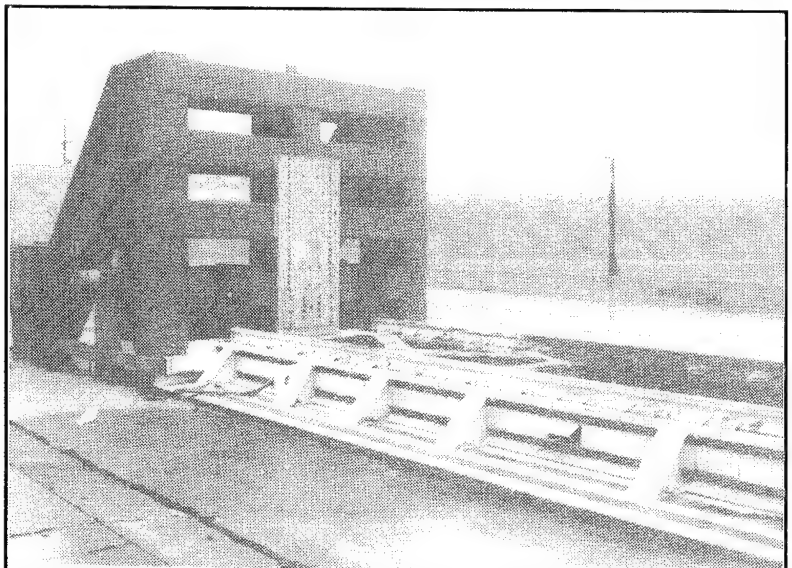


Figure 51. Engine mount at Horizontal Test Stand (Allred/Space Center 1994).

When the HSTT received previously-used liquid fuel engines, it was necessary to run tests on the engines. Since the engines were used, it was felt that the 'rated thrust' would be less than what it was when they were new. The used engines were mounted on the test fixture at the HTS, pressure transducers were installed to determine the amount of thrust, and the engines were operated (Figures 51 & 52). This enabled Test Track personnel to determine the thrust profile that could be obtained from the engines and, since the thrust profile was vital for meeting the test parameters on sled runs, the HTS did serve a useful purpose. The HTS facility included related controls, monitoring, and sensing instrumentation. A closed-circuit television system made possible indirect observation of a test in progress. The data collection instrumentation consisted of six strip-chart recorders and one 36-channel oscillograph, together with a time sequence recorder. [135]

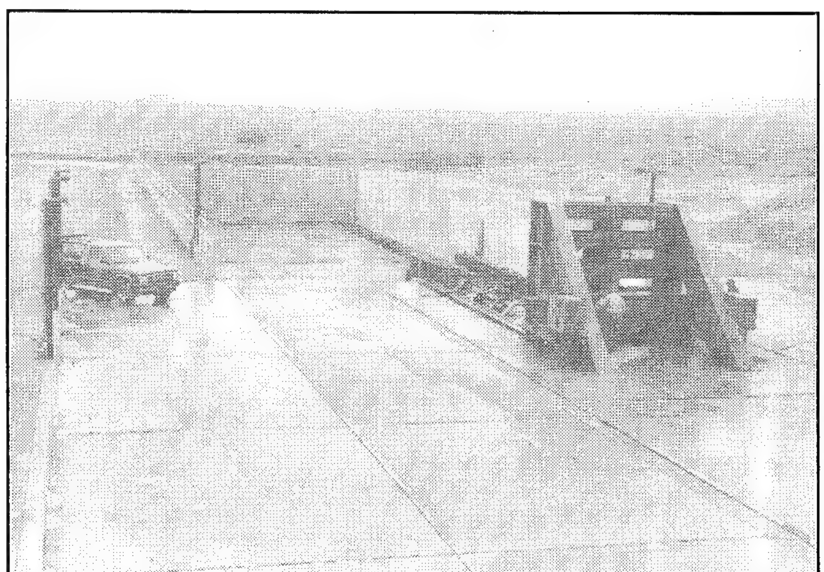


Figure 52. Engine mount and flame bucket at Horizontal Test Stand (Allred/Space Center 1994).

On several occasions the HTS was used for tests other than those for which it was originally envisioned. B-1 escape capsule fin deployment tests and OV-10A ejection system service life extension tests were conducted using this facility. The HTS is currently in use on an 'as needed' basis about two or three times annually.

Architectural Perspective

The HTS has been documented as a potentially historic structure during a HAFB architectural assessment, so only a brief discussion is presented here. The HTS facility is within a 637' x 490' area (Figure 53). It consists of the static motor mount surrounded by a concrete apron with water deluge nozzles, and with a concrete-lined, rectangular flame bucket to the north. Concrete covered dirt revetments are to the south and east, and a reinforced concrete Control Building (Building 1160) forms the west side of a roughly u-shaped berm around the motor mount. The two story, five room structure is 32' x 84' with 2688 SF of interior space, and has slit windows facing the test stand. Rooms include the observation room, recorder room, work shop, latrine, and mechanical equipment room. A pump house (Building 1159) is in the eastern revetment. This structure is 32' x 48' with 1536 SF of interior space. Both buildings were completed in 1957 and have concrete foundations, floors, walls, and roofs. There is also a fuel storage area cut into the southern revetment, fuel sumps, a leach field, and a septic tank. Fuel disposal tanks were once located just south of the facility, and a water storage reservoir was to the east. [136,137]

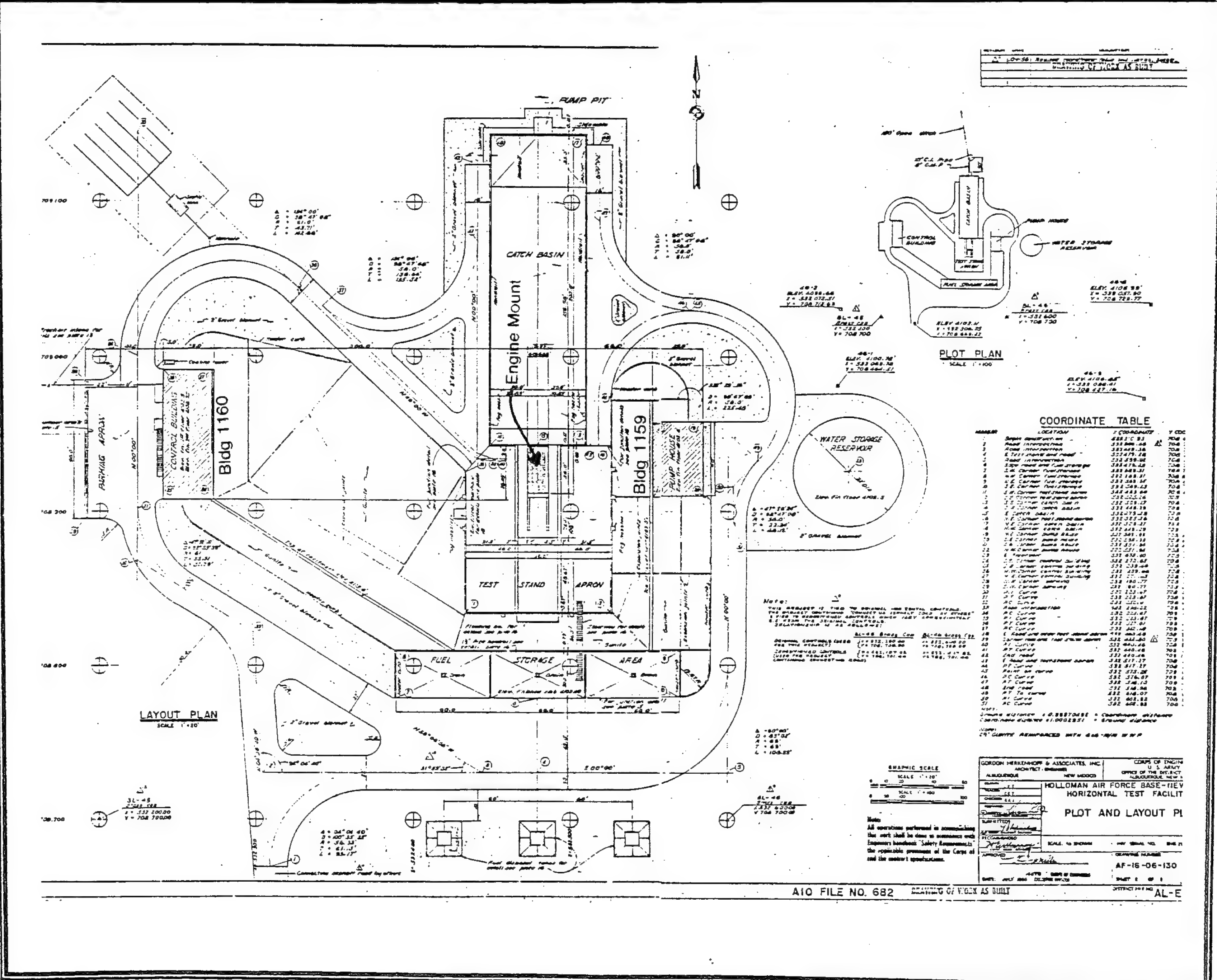


*Figure 53. July 1956 plot and layout plan of the Horizontal Test Stand.**

* *US Army Corps of Engineers - Office of the District Engineer, "Horizontal Test Facility - Plot and layout plan" (Albuquerque: July 1956) A10 File No. 682, CECNC, HAFB.*

INSTRUMENTATION FACILITIES

A variety of instrumentation was used on HAFB to support the missile and rocket test programs discussed previously. Instrumentation facilities as of 30 September 1950 included 9 Askania cinetheodolites (designated 'Peter'), 3 servo-tracked cameras consisting of modified B-29 turrets mounted with Mitchell high speed cameras ('Mike' or 'Yoke'), 3 Clark New Products Ribbon Frame cameras with permanent mounting piers ('Item'), 4 SCR-584 S-band radar sets ('Sugar'), 4 SCR-584 X-band radar sets ('X-Ray'), 4 radar plotting boards (connected to X-Ray, Sugar, and Baker facilities), 4 M-2 Optical Trackers (connected with Sugar and X-Ray facilities), 1 AN/TPS-5 Doppler Radar set ('Zebra 1'), 1 stationary four-band FM-FM telemetering receiving station ('Jig-1'), one stationary pulse-time telemetering receiving station ('Jig-2'), 1 time standard system (transmitting from 'Queen 1'), and 1 communications system comprising a command network. On 18 January 1949, the contract for operation and maintenance of the instrumentation sites was let to Land-Air, Inc. of Chicago, Illinois. This contract included facilities previously operated by HAFB enlisted men, the Boeing Airplane Company, the Glenn L. Martin Company, and the Hughes Aircraft Company. A typical array of instruments used for a test program is illustrated for the Aerobee ground-to-air research projects which used "five Askania cinetheodolites, two servo-tracked cameras, two Clark New Products Frame cameras, two SCR-584 X-band radars with plotting boards and boresights and data box cameras, one time standard system, two communication networks." [1,2]

Physical remains of many of these facilities are located throughout the base, but many concrete pads and camera stands could not be identified to a specific instrumentation type. Only Askania cinetheodolite stations were positively identified and, for that reason, they are the only type of instrumentation facility discussed here. The physical remains of six facilities were investigated, including three Missile Theodolite Towers and three fixed camera ground stations. Two of the fixed camera stations were located within the MTSA (HAR-041/LA 104274), and the remaining four facilities were documented as archaeological sites (see Figure 4). The instrument stations are discussed by their facility names, when possible.

Cinetheodolite Stations

Historical Background

As part of the early missile programs on HAFB, launches of items such as aircraft, missiles, and drones were visually tracked during flight to obtain information regarding the azimuth, elevation, altitude, range, attitude (nose up or down, yawing to left or right, or rolling to the left or right), and the position of the control surfaces. The stations that obtained such data ranged from simple camera pads to concrete German-designed photo towers, both equipped with visual observation and recording equipment such as the German-made 35mm 'Askania' cinetheodolite camera. These stations were operated

in conjunction with telemetering equipment and were accurately timed. [3]

The Askania cinetheodolite was an instrument that consisted of a photographic objective lens and a pulse operated camera mechanism supported on a yoke and base structure so the line of sight of the objective lens could be rotated through 360 degrees in azimuth and slightly more than 180 degrees in elevation (Figure 54). The AFMDC Facilities Guide for September 1959 outlined technical information for the Askania equipment. The lens and focal length varied from 20 inches at f/5.6 to 19 inches at f/16.5. The horizontal and vertical fields of view varied with the lens size; with the 20 inch lens, the field of view was approximately four degrees, and with the 19 inch lens it was only 3/4 of a degree. Shutter speed was approximately 1/150 of a second. [4] The camera had a film capacity of approximately 125 feet of 35 mm film, which afforded about fifteen minutes of recording time when operated at one frame per second, and approximately three minutes when operated at the normal operational recording rate of five frames per second. The accuracies of the Askania cinetheodolite under average recording conditions was less than one minute of arc. [5] At a distance of one mile, this would equate to 18.3 inches, or the approximate width of the dual headlights on an automobile.

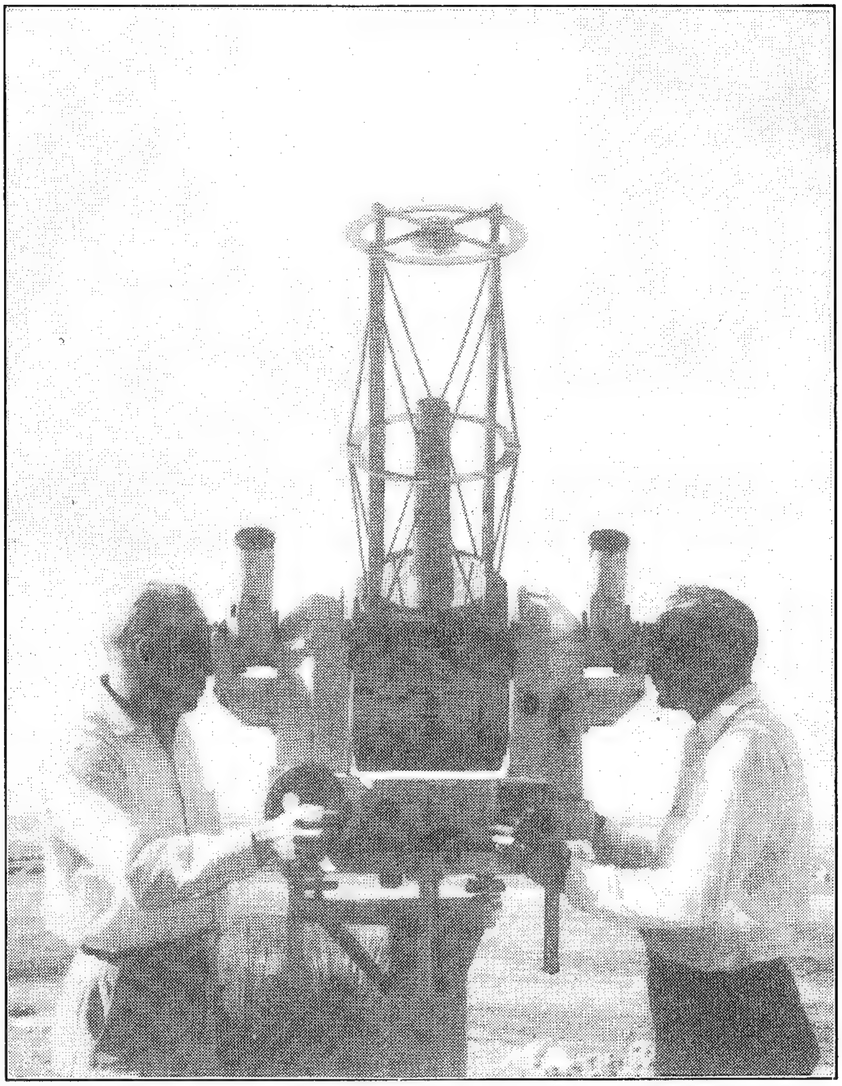


Figure 54. Askania cinetheodolite camera at a fixed camera ground station on HAFB, ca. 1948. Bud Fundt is on azimuth control (L) and William Allen is on elevation control (R) (Photo courtesy of Robert Montgomery).

The primary purpose of the Askania was to provide position and/or trajectory information on test objects, from Aerobee research rockets, drones, air-to-air missiles, ground-to-air missiles, air-to-ground missiles, to aircraft. Basically, a cinetheodolite was an arrangement of two photographic cameras, the plates of which were brought into exactly the same plane. Cinetheodolites operated on the same principle as a standard camera with a long-range telescopic lens system. Each camera was a motion-picture camera with the shutter mechanism accurately synchro-

nized with electronic timing by means of a common timing-control unit. From the differences between two pictures taken at the same instant, measurements in all dimensions of the target object could be obtained.

To accomplish this task, each instrument recorded a line of position from the station to the test object. Since a single station gave a single line of position, it was necessary to schedule multiple stations so there were two crossing lines of position. The intersection of these two lines determined the location of the test object. [6] The instrument included an elevation and azimuth optical angle data system which recorded the angular data on film at the same time that the photograph was recorded through the main objective lens. In operation, the objective lens was pointed at the target by rotation of the elevation and azimuth handwheels. The target image, the azimuth and elevation angles to the target, together with timing information, were photographically recorded in each frame.

When the test object had a high rate of speed, an extended ground track was necessary. At Mach 1, the speed of sound, speed is close to 1,000 feet per second and it was easy to pass through the effective area of an Askania in a short time. The proposed ground track would be determined and cinetheodolite stations along the proposed track would be scheduled to support the missile. This insured there would always be a minimum of two stations tracking the test object at all times. When multiple stations were used to track the test object, they were all linked together by a common timing signal in order that a particular set of data, two lines of position from two different stations, corresponded to a single point in time. Time could be broken down into millisecond (1/1,000 of a second) units.

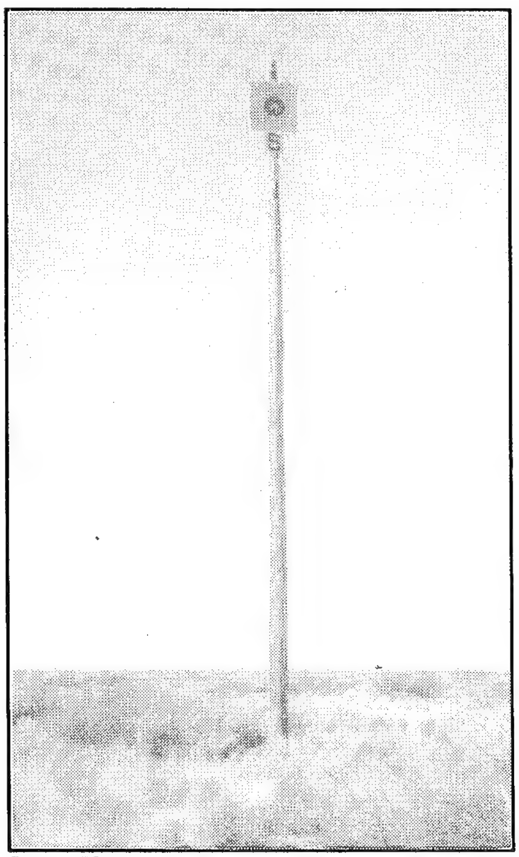


Figure 55. A typical calibration target pole: No. 5 pole south of the Sole site (Tagg/HAFB 1995).

Associated with the camera was a theodolite, consisting of a telescope mounted on a pedestal so it could be moved up or down and rotated horizontally through 360 degrees. The pedestal was the center of a horizontal circle with the azimuth scale markings. There was also a vertical scale to indicate the elevation or depression angle of the instrument. [7] Theodolite telescopes were generally about 20 power and had a narrow field of view of about 2 degrees. Cross hairs were provided for accuracy in keeping the optical system on the target. Like any precision instrument, the telescopes were constructed with extreme care and were highly accurate instruments. As a result, they had to be handled with care and protected from heat, moisture, and severe shock to prevent degrading their accuracy. [8]

Surrounding each cinetheodolite station was a circle of telephone poles which contained optical targets used for instrument alignment (Figure 55). These poles were arranged in a

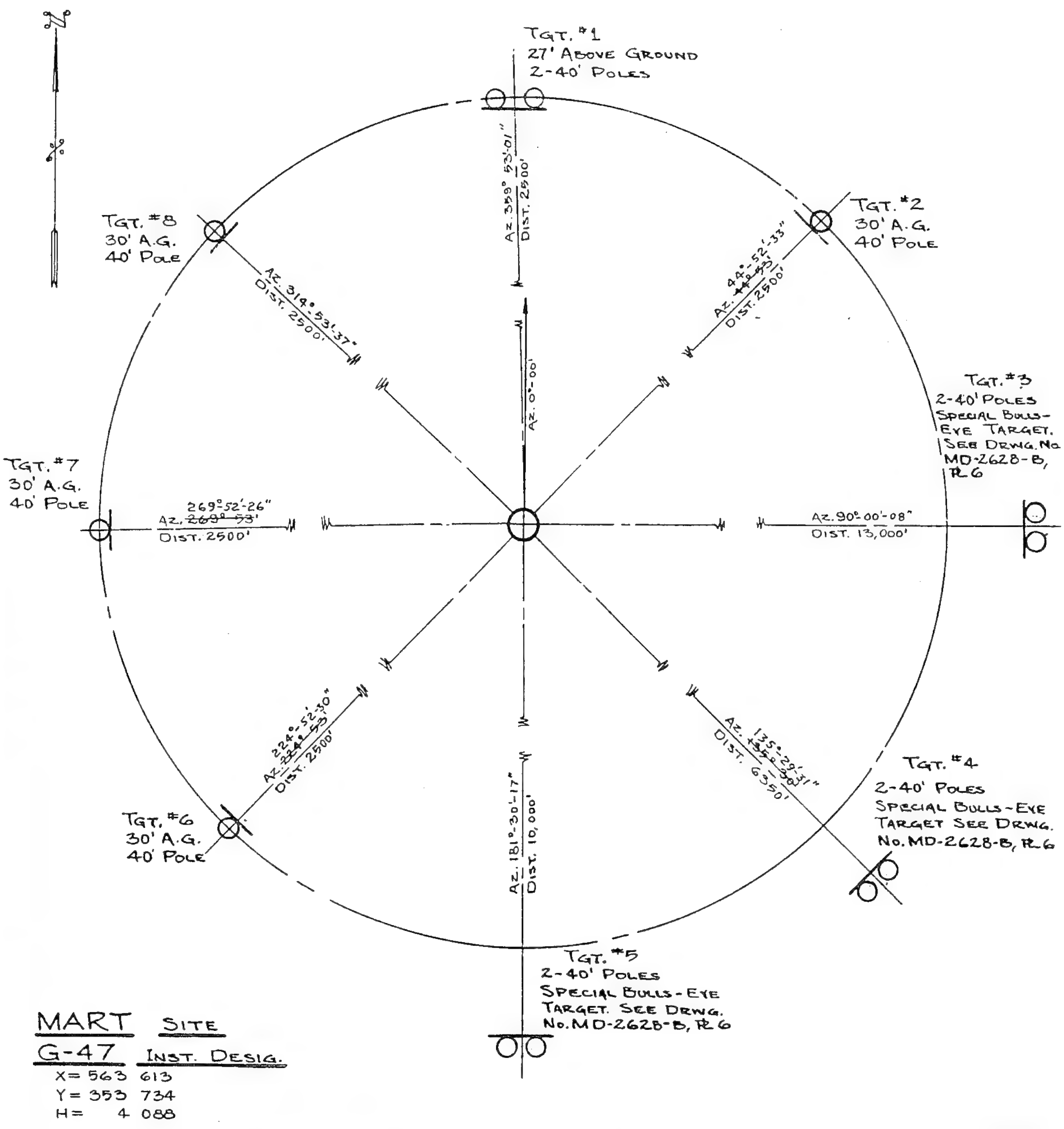
circular array around the station at distances ranging from 2,500 feet to 13,000 feet, normally with a double pole arrangement at each cardinal direction and a single pole at 45 degree increments between the cardinal direction (Figure 56). Prior to obtaining data during live missions, the theodolite had to be aligned to these targets, a process which took between three and five minutes per cycle of alignment, depending on the proficiency of the operator. [9] Four cycles, two for azimuth and two for elevation, were required prior to each mission. [10]

After the test, the cinetheodolite film was developed and put through a data reduction process involving frame-by-frame analysis. As each frame was flashed on a screen, the data reduction operator placed the cross hairs on a pre-selected point and depressed a switch. This operation was accomplished for each frame and refined the position of the selected point with reference to the cross hair location from the phototheodolite. The data was fed into a computer, where a program took the data from multiple stations and generated X, Y, and Z coordinates with respect to time. The computer program was refined so it gave the operator latitude, longitude, and altitude (X, Y, and Z). By further comparison of the data, velocity and acceleration could be generated. Other data, such as flight attitude, booster separation, and subsequent stage ignition, could also be obtained from the cinetheodolite film.

When the cinetheodolite stations were first constructed, it was the responsibility of a two man team of operators to find and track the test object. They would have to know the approximate azimuth and elevation where target acquisition would occur. Later, radar pointing information was furnished to the Missile Theodolite towers. This target acquisition data was developed and installed by Radio Corporation of America (RCA) and the necessary equipment was installed on the second floor of the tower. There were two dials, one for elevation and one for azimuth, and the operators had to ‘zero out the needles’ to have the Askania camera pointed in the vicinity of the target. At this point, the radar acquisition would be uncoupled and the operator would manually track the target. Basically, the initial radar coupling gave ‘course’ pointing data and the operator furnished the ‘fine’ tuning. Later, as the pointing system was refined, the accuracy of the radar pointing data was improved and the operator would remotely control the Askania camera system. [11] The Askania operators could not keep the crosshairs on a specific point on the target during the entire mission because of the length of time involved. This introduced a small error which was removed during the data reduction process described above.

The first cinetheodolite stations, probably dating from the initial missile testing programs in 1947, consisted of the cinetheodolite equipment mounted on an instrument pedestal on a concrete pad (Figure 57). These fixed camera ground stations were known as ‘Peter’ sites (for phototheodolite). Adjacent to the pedestal was a 12' x 16' “tar paper covered NAA type cinetheodolite utility building” for housing electronic and control equipment used in conjunction with the cinetheodolite. The instrument stayed on the pedestal and was protected by a canvas cover when not in use. [12] The protection provided by the cover was not ideal for use in a desert environment, which was one rationale for construction of the Missile Theodolite towers.

The German-designed towers were initially constructed in 1954, with later modifications between



REVISION	DATE	DESCRIPTION	BY
1	16 JULY '63	ADDED "AS BUILT" & SURVEY	

WHITE SANDS MISSILE RANGE, N.M. INTEGRATED RANGE MISSION MEASUREMENTS DIVISION	DRAWN CHECKED DATE 29 NOV. '61 SCALE NONE	CINETHEODOLITE TARGET INSTALLATION TYPE "B" @ MART SITE DRWG. NO. MD-2713-A PLATE 53
APPROVED / APPROVED CHIEF, MD		

Figure 56. A typical target pole array around a cinetheodolite station: the Mart site array in 1963. *

* *From "Missile Theodolite Towers" file in Space Center archives, n.d.*

1962 and 1963, to record ground-to-air projects. They were also referred to as Askania towers because of the German-made 35mm Askania cameras used in them, or as Phototheodolite sites, and the Air Force had a name and number designation for each facility.[13] The building was described as an Air Force type three-story cinetheodolite building of monolithic concrete construction with a four-section, electrically-operated, slide-down roof (Figure 58).

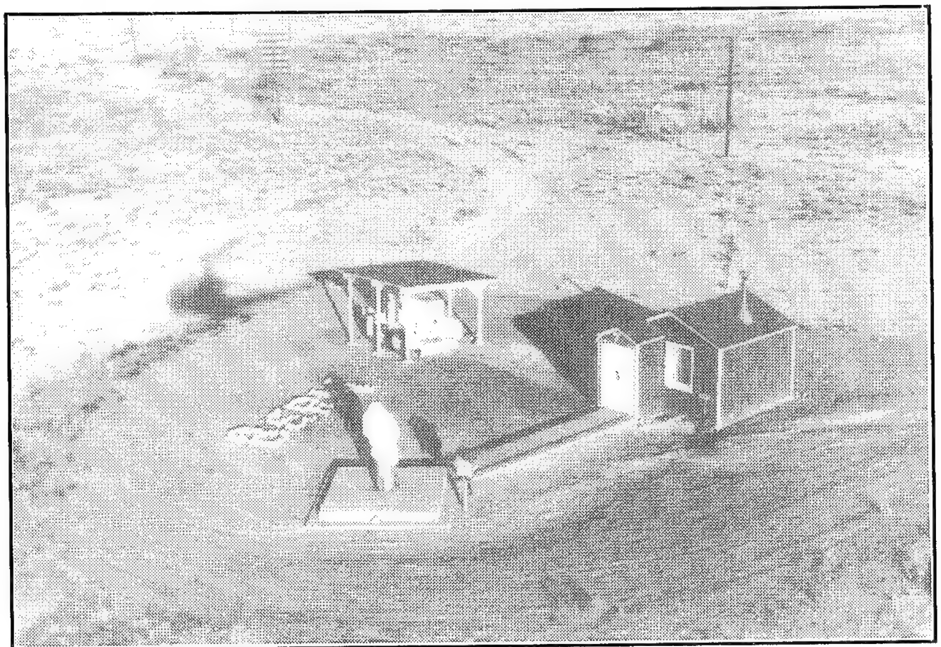


Figure 57. Bern site cinetheodolite ground station at HAFB looking east, 26 November 1963 (Photo courtesy of WSMR Museum).

Each building contained 60,000 BTU butane heaters on the first and second floors with fuel stored in a 499 gallon tank located beside the tower (Figure 59). Cooling during the summer months was furnished by two 1,800 cubic-feet-per-minute evaporative coolers (Figure 60). Commercial electrical power or portable generators were used for operation of the roof, lights, and instrumentation. No water lines were laid to the towers, so two 150-gallon tanks provided water for drinking and washing.[14]

Today, three of these towers can still be seen on HAFB, including the Mart site (G-47) just northwest of the runways, the Pritch site (G-56) west of the High Speed Test Track, and the Sole site (G-58) at the north end of the base (see Figures 58-60). In addition, three fixed camera ground stations have been documented, including the Bern site and two facilities in the MTSA. None of these facilities are in operative condition, but the physical remains and the basic structure of the towers give testimony to the instrumentation aspect of missile and rocket testing on HAFB.

Archaeological Perspective

The exact number of cinetheodolite stations which existed on HAFB is unknown at this time. Nine facilities, located at stations Peter 1, 3, 5, 6, 7, 8, 9, 10, and 13, were listed on a 30 September 1950 military inventory, and Peter 2 and 11 are illustrated on an undated instrumentation facility location map.[15,16] This map, in addition to others, shows facilities scattered throughout HAFB from Peter 1, which was approximately 1,000 feet east of the Mart site, north to Peter 11 on Tularosa Peak. Six of these facilities have been documented at the time of this research, although the remains of more are likely to be found as additional cultural resource inventories are completed. Four stations, including 3 Missile Theodolite towers and a fixed camera ground station, were recorded as archaeological sites

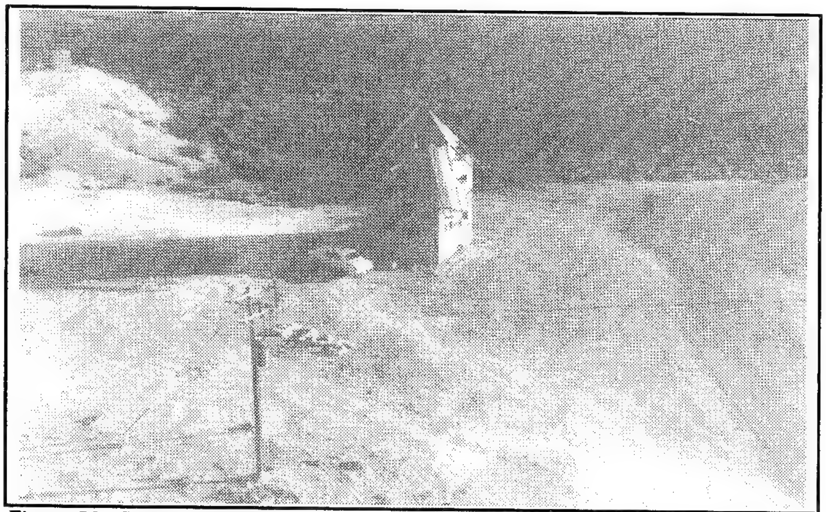


Figure 58. Sole site Missile Theodolite tower at HAFB, looking southwest, 26 November 1963 (Photo courtesy of WSMR Museum).

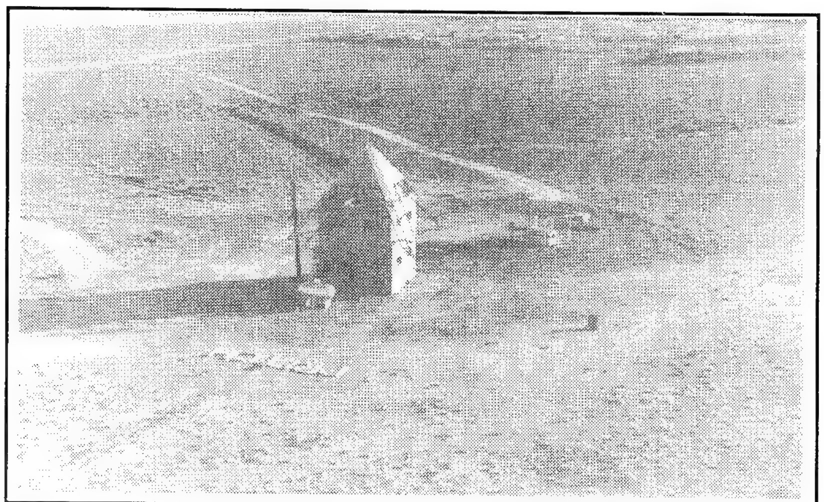


Figure 59. Pritch site Missile Theodolite tower with propane tank and temporary generator shelter, looking south, 26 November 1963 (Photo courtesy of WSMR Museum).

Figure 60. The Mart site Missile Theodolite tower, with covered cinetheodolite under open roof and evaporative coolers in front of the building, looking south, 26 November 1963 (Photo courtesy of WSMR Museum).

(see Figure 4). Two additional ground stations were features within the MTSA. The three towers have also been documented as historic structures. [17]

The three Missile Theodolite towers were completed in 1954 using identical construction specifications. The three-story towers have reinforced concrete foundations, floors, walls, and ceilings. They are 17' 8" square with 584 SF of interior space. The first and second stories are concrete and stand 16' 8" high. Each tower has a 3' 11" high third level constructed of plywood which is covered with a retractable, peaked, four segment, aluminum roof. When in use, this roof was operated with a hydraulic system using a concrete counterweight connected to a steel I-beam with a steel cable. The roof segments slid down the exterior framework and exposed the third level platform where an Askania cinetheodolite camera was mounted on an instrument stand (see Figure 60). All the towers have a single hung metal entrance door, one to four rectangular windows on each side, a concrete stairway to the second floor, and a metal ladder through a small hatch to the upper level. Concrete slabs, measuring 5' x 17' 8", with two raised pads attached to the front of the building, originally supported water storage tanks. [18,19,20]

The towers also had associated external features, including eight target poles in an array around the tower (see Figure 56). The poles varied in distance from the tower. They were normally 40 feet above ground level (AGL) with a single or double "special bulls-eye target" attached to the top. The targets were small, square, and described as "board metal," with a black circle drawn on them and a small hole in the center (see Figure 55). [21]

The fixed camera ground stations each consist of a series of concrete pads with steel tracks and a steel instrument stand. The main instrument facility at each station had two 12' square pads 30 feet apart and connected by a 5' wide sidewalk. Two steel tracks, 3' 6" apart, connect the two pads along the sidewalk. One of these pads had a raised 10' square concrete bench with a metal instrument stand in the center. No superstructure remained at the facilities, with the exception of scattered lumber. Associated external features are present, including footings for an open shed which housed a mobile generator.

Mart Site (HAR-018r, LA 107798)

The Mart Site, also known as 'George 47,' consisted of a Missile Theodolite tower (Building 900) and eight associated features (Figure 61). The site was documented for this project by the HAFB Archaeologist. [22] It is located just north of HAFB Runway 04-22 on a flat alluvial plain at an elevation of 4,071 feet ASL (see Figure 4). The tower (Feature 1), facing east, is in excellent condition and matches the specifications described above (Figure 62). The 1' 6" square concrete block counterweight, with an iron attachment hook, is lying beside the structure. An undated HAFB inspection form indicated the air evaporative coolers, electric hoist, hydraulic lift, butane tank, and air coolers had been removed. [23] A gravel drive is in front of the building. Four power poles are situated around the tower, and a power line runs to the northeast.

Feature 2 has two rectangular, 3' 4 " x 8" x 1' 6" concrete footings for the missing 499-gallon butane

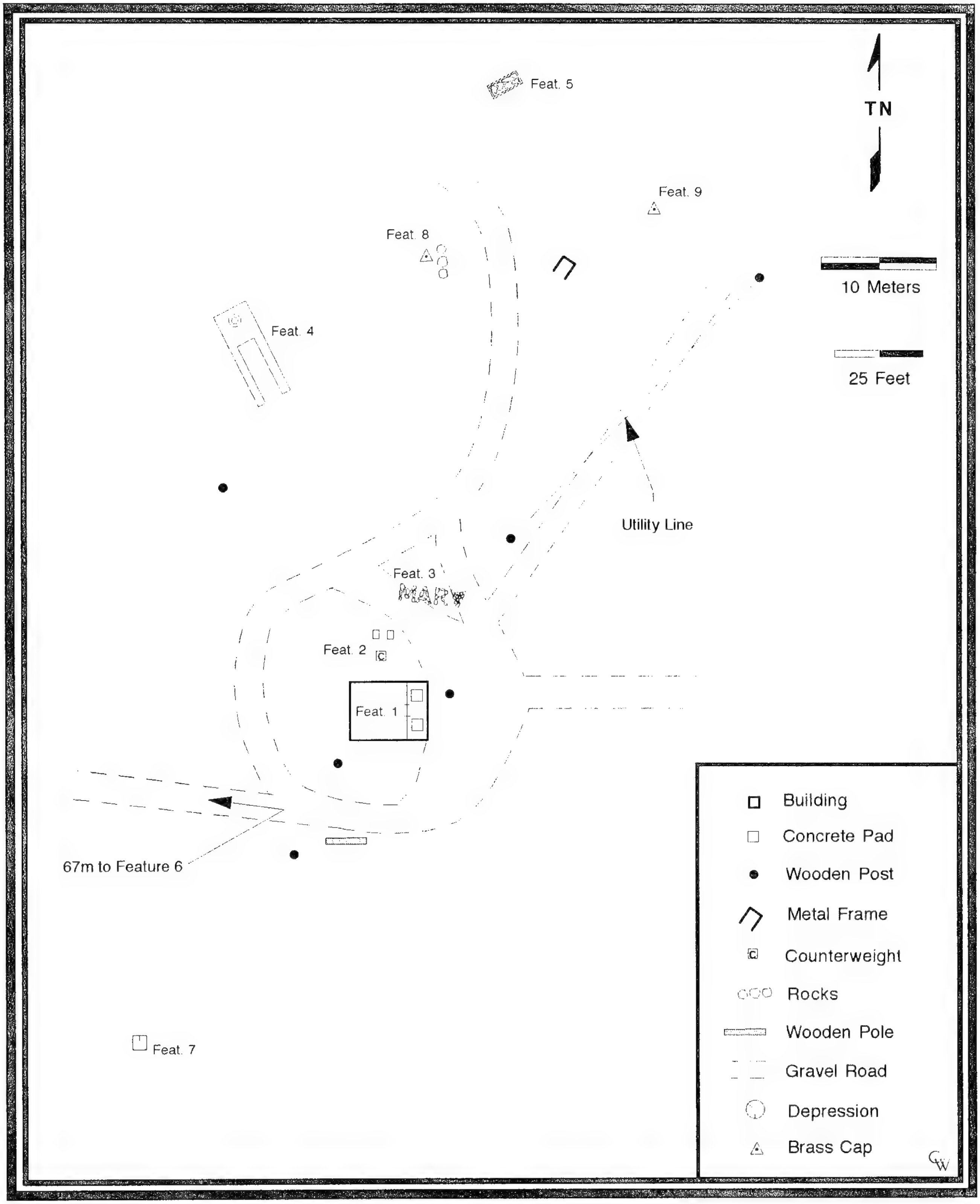


Figure 61. Mart site (HAR-018r, LA 107798) map.

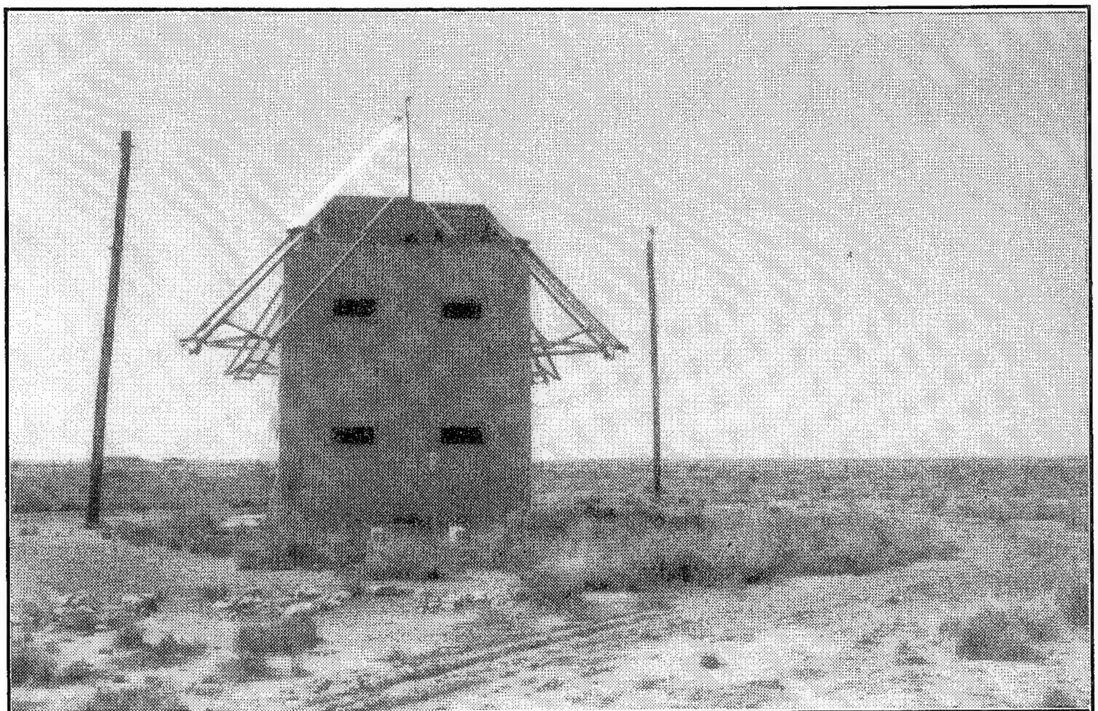


Figure 62. Mart site Missile Theodolite tower, north elevation, with rock-aligned facility name, footings for propane tank, and counterweight (Allred/Space Center 1994).

tank. A Mitchell vaporizer is connected to an upright metal pole beside the footings. Feature 3 is a 24' x 5' rock alignment spelling "MART," the facility name. The "T" has been disturbed by an active dirt road. Feature 4 consists of a 9' 6" x 7' concrete pad northwest of the tower. The pad has two linear, 21' x 2' concrete pads with metal skids extending to the south, and a round, 3' 8" diameter elevated pad in the center (Figure 63). A brass cap with "P-19 WSPG >—> No. 4 1968" is imbedded in the northeast corner of the pad. Feature 5 is a 7' 6" x 3' 6" wooden frame filled with cobbles. Feature 6 has a 4' 6" square aluminum and wood vault covered with a metal lid within a 12' square wooden frame. A 49' x 39' area, with the vault in the center, is covered with chicken wire secured to the ground in the corners with wooden stakes. Feature 7, a 2' 6" diameter, 2' 6" deep depression, is all that remains of the latrine. Features 8 and 9 are White Sands Proving Ground brass caps. Feature 8 is stamped with "P-19 1954" and is protected by three large rocks, and Feature 9 has "P-19 No 2" on it. In all probability, the 'P-19' stands for 'Peter 19.'

The eight target poles are intact and consist of four single poles and four double poles, all with targets attached. With the exception of the target on Pole No. 1, which is 27 feet AGL, all targets are 30 feet AGL. Three of the targets, on poles 3, 4, and 5, are described as "special bulls-eye targets" (see Figure 55). Table 9 lists the number of poles and distance and azimuth of each target from the tower. [24]

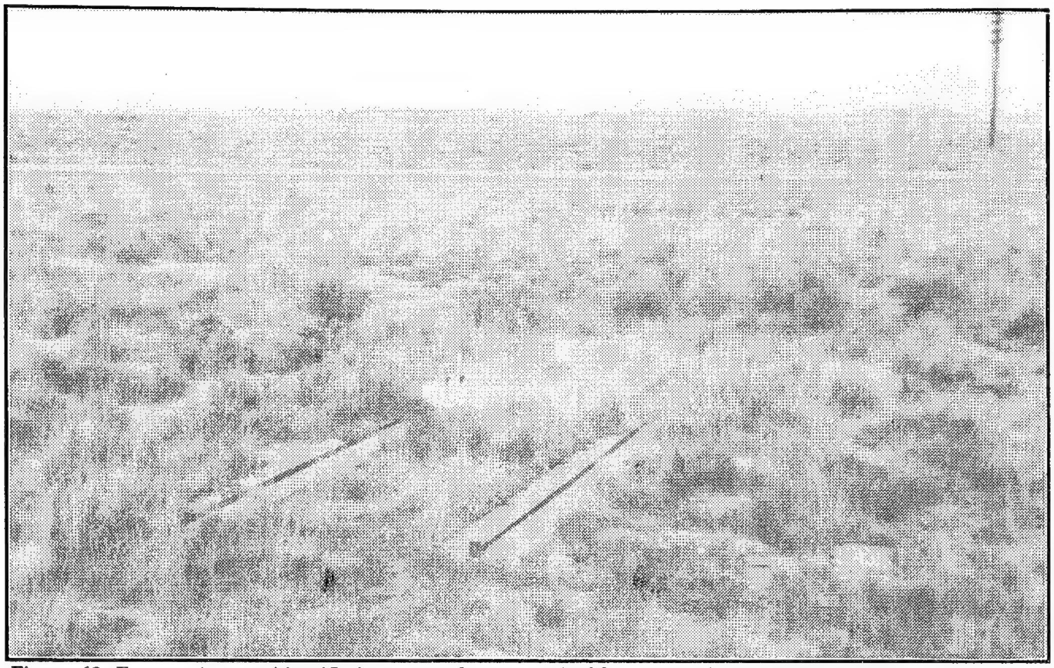


Figure 63. Feature 4, an unidentified concrete feature at the Mart site (Mertens/HAFB 1995).

Table 9
Mart Site Target Poles

Target No.	Poles	Azimuth	Distance
1	2	359°53'01"	2,500'
2	1	44°52'33"	2,500'
3	2	90°00'08"	13,000'
4	2	135°29'31"	6,350'
5	2	181°30'17"	10,000'
6	1	224°52'30"	2,500'
7	1	269°52'26"	2,500'
8	1	314°53'37"	2,500'

An undated military report with an 30 August 1960 plan map identifies the Mart site as a "Low Speed Cinetheodolite" station with the tower (Air Force Building No. 900, Army No. 29600) and a latrine (No. H-4200).[25] A series of 1963 photos of the site show the tower, propane tank, latrine, and the facility name spelled in stone (see Figure 60). The Feature 4 concrete foundation is also visible in one of the photos, appearing then as it does today. This suggests it may predate the Missile Theodolite tower. Also shown in the pictures are two trash barrels and what appears to be wooden post parking curbs. Presently, no evidence remains of the trash barrels, and a 4" x 4" wooden post lying near the building may be one of the parking curbs. There is no record of additional buildings or facilities associated with the tower, implying that Features 5 and 6 are later additions to the area. The function of

these features is unknown. The presence of the Feature 4 pad, apparently predating the tower, and Features 5 and 6 which may be more recent, suggests the site was used for purposes other than as a cinetheodolite station.

Pritch Site (HAR-007, LA 99633)

The Pritch site, also known as 'George 56' and perhaps 'Peter 6,' consists of a Missile Theodolite tower (Building 1133) and six associated features (Figures 64 & 65). The site was documented in 1993 by the HAFB Archaeologist as part of a Test Track Site Documentation project. [26] It is located west of the High Speed Test Track, on a flat alluvial plain surrounded by active sand dunes at an elevation of 4,067 feet ASL (see Figure 4). The building (Feature 1), facing east, is in excellent condition. The only noticeable damage is broken window glass and a cracked window in the front door. A gravel and dirt road circles the tower. The concrete block counterweight, still connected by a steel cable to the I-beam boom, is lying beside the structure, and a power pole is in front of the building. The evaporative coolers and water tanks which faced the structure were removed between 1964 and 1968. [27]

Feature 2 is a 499-gallon butane tank on two 3' 4" x 8' x 1' 6" concrete footings. A Mitchell vaporizer is attached to a metal pole beside the tank. Feature 3 is a 28' x 5' 6" rock alignment spelling "PRITCH," the facility name. Feature 4 is an intact one-seat latrine which is 4' 3" x 5' 2 " x 8' and constructed of wood planks with a low gable, tarpaper-covered roof and a doorway in the south wall. A weathered toilet paper roll is still sitting on the bench seat. Feature 5 is a 50-gallon trash barrel filled with tin cans, bottle glass, pyrotechnic devices, a car battery, and metal scraps. The temporary open generator shelter, Feature 6, is a 12' x 11' 6" x 8' 6" ramada with six 4" x 4" wooden legs on 1' square concrete footings supporting a slightly pitched tarpaper shed roof. Feature 7 consists of two sets of two 50-gallon barrels set horizontally on metal frame legs. A black metal pipe runs from the tanks into the ground. They apparently once contained gas or oil for the generator.

Two USGS brass caps, Feature 8, are located approximately 100 feet northeast of the tower. They are inscribed with "PRITCH 1968." One of the caps also has "No 2" on it. A broken-up concrete pad, Feature 13, lies 49 feet to the northeast of the tower. Approximately 165 feet southwest of the tower are four features which appear to be test wells. There are two concrete pads with steel pipes set in them, a pile of gravel, and a pile of railroad ties. There is no evidence which suggests these features are associated with the Missile Theodolite tower.

Seven of the eight targets are intact, consisting of six single poles and one double pole with targets. The location of the missing pole, Pole No. 2, is currently within an area with numerous power poles and may have been adapted for alternate use. With the exception of the target on Pole No. 1, which is 27 feet AGL, all targets are 30 feet AGL. Table 10 lists the number of poles and distance and azimuth of each target from the tower. [28]

An undated military report identifies the Pritch site as a "Low-Speed Cinetheodolite" station with the tower (Air Force Building No. 1133, Army No. 29562), a temporary open generator shelter (un-

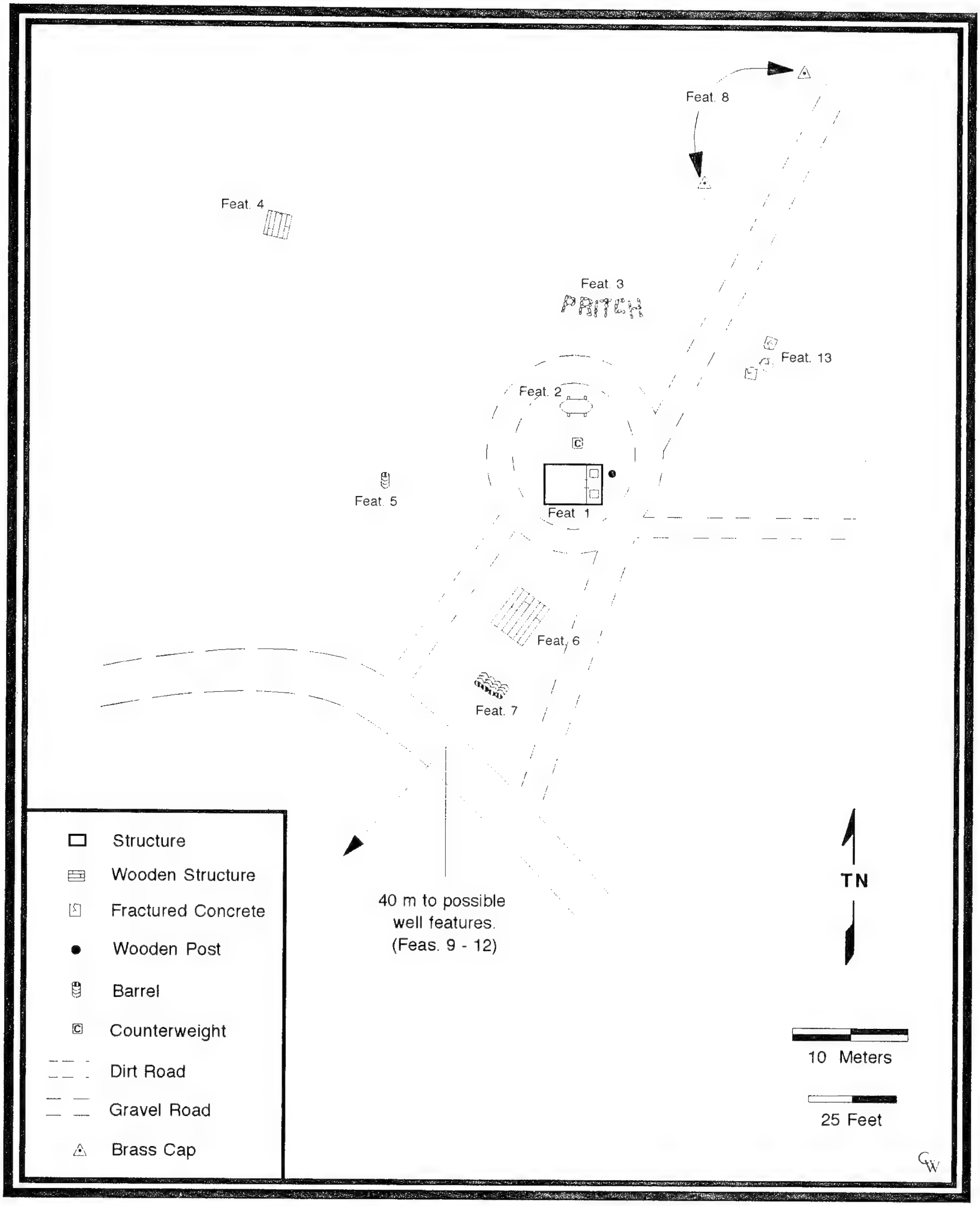


Figure 64. Pritch site (HAR-007, LA 99633) map.

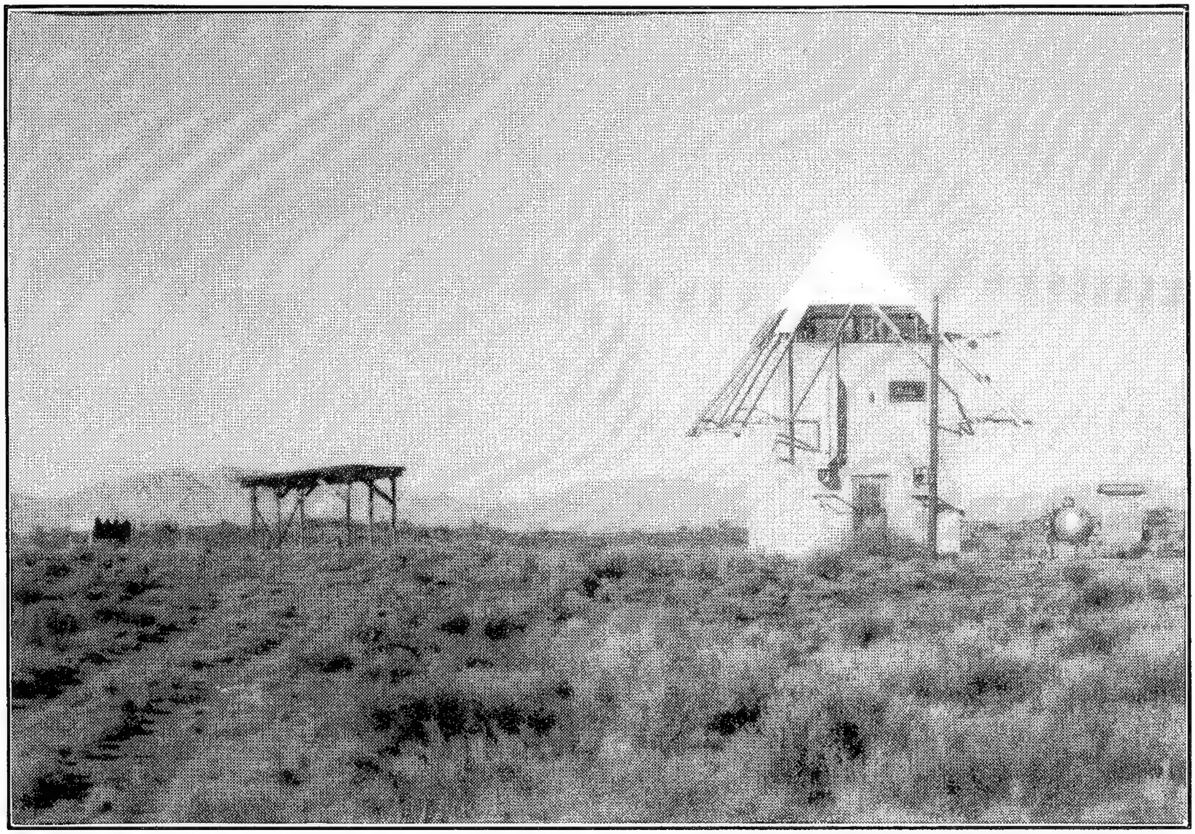


Figure 65. The Pritch site in 1993, looking west with (L-R) fuel barrels, generator shelter, Missile Theodolite tower, counterweight, propane tank, and latrine (HAFB CRM files).

Table 10
Pritch Site Target Poles

Target No.	Poles	Azimuth	Distance	Remarks
1	2	00°00'13"	2,500'	
2	1	44°59'13"	2,500'	missing
3	1	90°00'14"	2,500'	
4	1	135°00'12"	2,500'	
5	1	178°09'35"	2,700'	
6	1	224°52'17"	2,700'	
7	1	269°59'51"	2,500'	
8	1	314°59'10"	2,660'	

numbered), a latrine (No. H-4208), and the eight board metal target array. [29] There is no record of additional buildings or facilities associated with the tower, although features 5 and 7 (trash barrel and oil/gas barrels, respectively) are visible in a 1963 photo of the facility (see Figure 59). The site appears to have a single component, and there is no evidence the facility was used for any activities other than for its original function.

Sole Site (HAR-005, LA 99457)

The Sole site, also known as 'George 58,' consists of a Missile Theodolite tower (Building 1249) and 13 associated features (Figure 66). The site was documented by the HAFB Archaeologist in 1992 as part of the Building 1249 Disturbance project. [30] It is located on a flat ridge overlooking Malone Draw at an elevation of approximately 4,205 feet ASL (see Figure 4). The building (Feature 1), which faces east, has been extensively vandalized. There are bullet holes in the aluminum roof segments, front door, and the inside stairwell and walls. Spray paint and pencil graffiti is on the interior and exterior of the walls, and a number of the associated features have spray paint graffiti. The tower has been used during military maneuvers, and spent blank cartridges and pyrotechnic devices litter the area. Numerous padlocks have been broken off the front door, which has been strengthened with iron braces. The windows have been filled in with concrete to keep intruders out. A gravel and dirt road circles the tower, and gravel covers the ground in a large area around the features. The concrete block counterweight is lying beside the structure, and a power pole is in back of the building. A 7' x 3' concrete pad is attached to the south of the structure. The evaporative coolers, water tanks, and butane tank which were originally located next to the structure have been removed.

Feature 2 is two 3' 4" by 8" x 1' 6" concrete footings for the 499-gallon butane tank and a pole for a No. 2 Mitchell Vaporizer. Feature 5 consists of two concrete pads for a temporary cinetheodolite shelter. These pads are 10' 6" x 8' and 5' x 2' 10" in size. The large pad has attachment bolts around the edge, a 2' diameter circular rust stain where the camera stand was once attached, and an electrical sleeve with communications wire. The smaller pad has a 2" x 4" board frame and an electrical sleeve with communications wire. Feature 6 is a USGS brass cap with "1954 P-8" inscribed in it. In all probability, the 'P-8' stands for 'Peter 8.'

Feature 12 is a 10' x 6' concrete pad for a generator shelter. Features 13, 14, and 15 lie over 165 feet from the tower. Feature 13 has a 14' square concrete pad with a u-shaped 2" x 4" lumber foundation bolted to it and two wooden posts beside it. Iron rings are attached to each corner and milled lumber is lying around it. Additional lumber and two tin shed pieces, which probably represent the superstructure, are lying downslope. Feature 14 is a 10' square wooden frame on legs. It may be part of the superstructure of Feature 13. Feature 15 is 8' square by 7' tall tin shed on a 10' 4" x 10' wooden platform with steps supported by 3' 6" tall concrete block pillars. The shed has a low pitched shed roof, a wooden work bench and shelves inside, and two single hung tin doors opening to the north and south. A concrete pad under the northwest corner has "10/3/63 R. RIVELL M. LERUM, . . . BURK" inscribed in it.

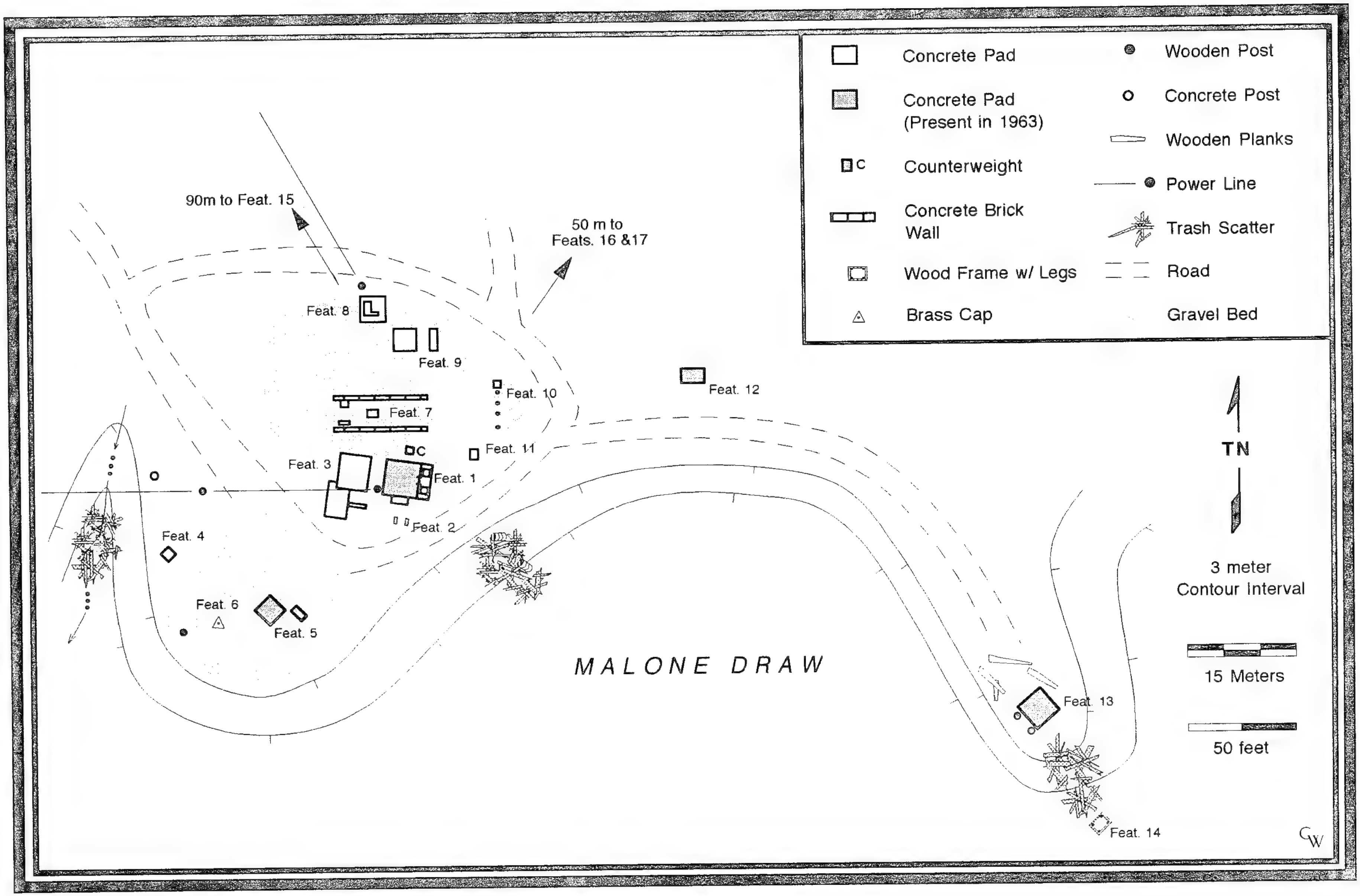


Figure 66. Sole site (HAR-005, LA 99457) map.

"RUSH" is painted in yellow on an inside wall, and a black winged symbol and "ENTER" is painted in yellow on the door. Feature 16 is a pile of plywood and 1" x 4" lumber and Feature 17 is a 4' 6" x 2' 6" x 6" depression. Both features may be the remains of a latrine. A power line runs west from the tower, and a second line runs northwest from Feature 8 to Feature 15. There are numerous antennae tie-downs and tent stakes in the area. The tower is situated on an aboriginal flaked stone scatter.

The remaining features are not directly associated with the original use of the Missile Theodolite tower. These are listed in Table 11. Four of the eight targets, which are on single poles, are intact. All targets are 30 feet AGL. Table 12 lists the number of poles and distance and azimuth of each target from the tower. [31]

Research has identified the site as either 'Peter' 3 or 'Peter 8'. The 'P-8' on the brass cap would suggest it was 'Peter 8,' which is listed on the 1950 inventory. [32] It is probable the 'Peter 8' listed on this inventory was the temporary pad (Feature 5), used before the tower was constructed in 1954. A 1960 map shows the tower, a temporary cinetheodolite shelter (Feature 5), and a generator shelter (Feature 12), as well as the target pole array. [33] Three 1963 photographs of the facility show the latrine, rock-aligned site name, a generator (Feature 12), the elevated structure (Feature 15), a 50-gallon trash barrel, and a small structure (Feature 13) (see Figure 58). There is no record of additional buildings or facilities associated with the tower. Features 16 and 17 may be evidence of the latrine, but they appear to be too far from the tower. The facility name would have been where the later features (7, 8, and 9) are today. The remaining features and the gravel apparently were added after 1963 and were not associated with the original facility. The function of these additional features is unknown. It seems apparent from the number of features postdating the tower that the site has been used for reasons other than its original purpose. An informant suggested that Feature 15 was constructed by the base Security Police for training purposes. The Missile Theodolite tower is currently used for calibrating survey instruments.

Bern Site (HAR-021, LA 102577)

The Bern Site, also known as 'George 54,' is a fixed camera ground station consisting of a cinetheodolite shelter pad and six associated features (Figure 67). The site was documented in 1993 by the HAFB Archaeologist as part of the Bern Site Documentation project. [34] It is located on a flat alluvial plain north of Malone Draw at an elevation of 4,248 feet ASL (see Figure 4). The cinetheodolite utility building (Feature 1) consists of concrete pads, a 3' 7" tall and 1' 6" diameter camera mount, and iron rails as discussed above (Figure 68). A 3' square, 1' 6" deep concrete conduit pit and three 2" diameter conduct pipes are beside the southern pad. The instrument stand is filled with concrete and has three power outlets at the base. Rebar is sticking out around the edge of the pad.

The facility name, "BERN," is spelled out with cobbles in a 20' x 6' 6" area (Feature 2). Feature 3, the open generator shelter, consists of six 1' square concrete footings in a 12' 3" square area. The pads are in lines of three and have two metal braces sticking out of each. A metal pipe is sticking up beside one pad and a scatter of nails is between the pads.

Table 11
Additional Sole Site Features

Feature No.	Description
3	15' x 18' concrete pad with numerous attachment bolts and circular and square rust stains. A 12'6" x 9' pad, with a 7' x 11' "wing wall" and three 1' diameter rust stains, is attached.
4	4' 6" x 3' concrete pad.
7	Two parallel 40' x 6' x 4' 9" concrete block walls set 15' apart. The walls have lumber attached to the top interior, and blue painted graffiti consisting of a star and "RUSH." Three 3' square concrete pads with 1'6" diameter rust stains and a recent camp fire ring are in the center. Guy wire attachment rings are just outside the feature.
8	11' 6" x 10' 6" concrete pad supporting a 5' tall concrete L-shaped pillar. Graffiti consists of a block of white paint (which appears to be a painted over word) and red paint splotches.
9	Two concrete pads, 10' x 8' and 8' x 3' in size. Vandalism consists of white paint splotches.
10	16' long alignment of four 6' tall iron posts, a metal 4-legged frame, and two electrical sleeves with communications wire, all set in concrete. Metal boxes, a metal grill, and metal warning signs lie around the posts. Most of these items have bullet holes in them.
11	3' square concrete pad with a hinged metal lid, possibly representing a septic tank.

Table 12
Sole Site Target Poles

Target No.	Poles	Azimuth	Distance	Remarks
1	2	00°00'00"	2,500'	missing
2	1	45°00'00"	2,500'	missing
3	1	90°00'00"	2,500'	missing
4	1	135°00'00"	2,500'	
5	1	180°00'00"	2,540'	
6	1	225°00'00"	2,500'	
7	1	270°00'00"	2,500'	missing
8	1	315°00'00"	2,500'	

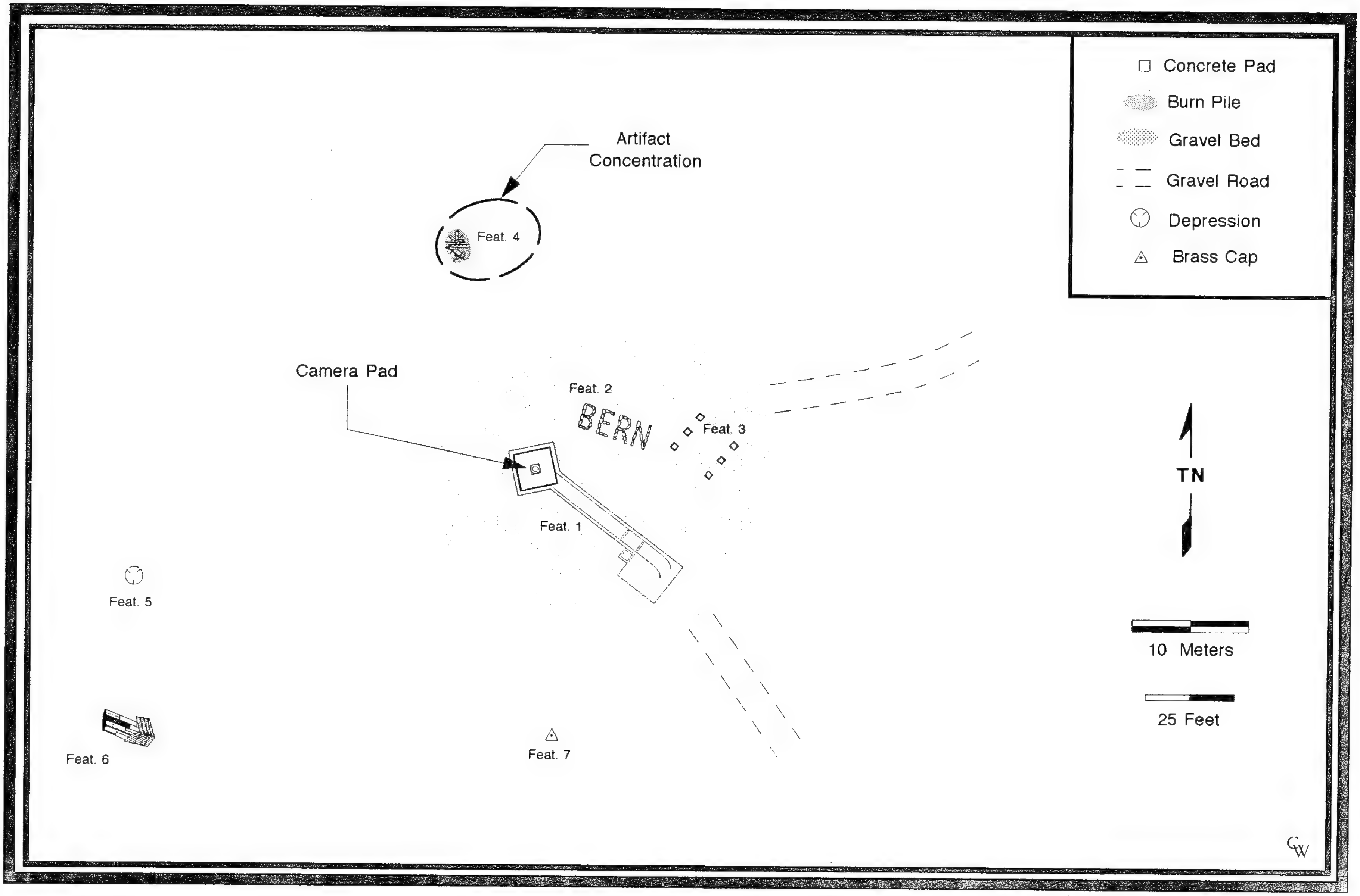


Figure 67. Bern site (HAR-021, LA 102577) map.

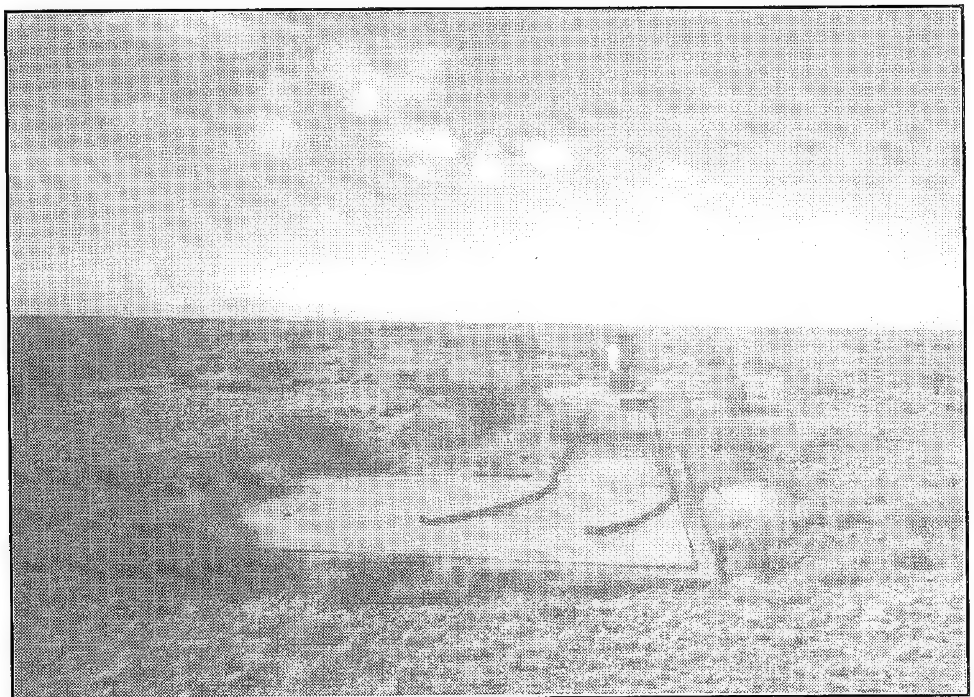


Figure 68. Bern site cinetheodolite shelter pad in 1993 with camera mount and iron tracks, looking northwest (HAFB CRM files).

Feature 4 is a 25' x 20' trash concentration with a 6' diameter burn pile at one end. Artifacts consist mainly of wire nails, hinges, bolts, Coke bottle fragments, scrap iron, and electrical wire connectors. Feature 5 is a 2' diameter, 8' deep, round depression with window glass, a nut, and a 4" x 4" wooden post beside it. The feature is probably the privy hole the overturned wooden latrine (Feature 6) lying 50 feet to the south of the hole. The structure is 5' x 4' x 8' 6" with a low pitched, tarpaper covered, gable roof. Numerous M-16 blank cartridges, .30-caliber cartridge links, and a cartridge bag are lying by the feature. Feature 7 is a brass cap set in concrete with the words "WHITE SANDS PROVING GROUND REFERENCE MARK/GEODETIC-CONTROL F.D.L./—>/P-7 NO. 2" inscribed on it. In all probability, the 'P-7' stands for 'Peter 7.'

Features 1-3 are within a 100 foot diameter gravel area. A gravel road and a two-track road connect the facility with the main road. One interesting artifact located in the area is a small metal tag with "U.S. GOV'T PROPERTY/LAND AIR/USAF NO. 5391." This may be evidence of Land Air's management of the facility after 1949, when that organization received the contract for operation of the instrumentation sites.[35]

All eight targets are intact, including seven on single poles and one on a double pole. The targets are 30 feet AGL, with the exception Target No. 1, which is 27 feet AGL. Table 13 lists the number of poles and distance and azimuth of each target from the tower.[36]

The site features are all associated with the original use of the facility as a cinetheodolite station. The site has been used more recently for military maneuvers, indicated by the numerous cartridges and military equipment in the vicinity. The latrine has apparently been overturned and moved from its original location. The facility may have been constructed prior to 1949, when Land Air undertook the

operation and maintenance of instrumentation facilities previously operated by Air Force enlisted personnel. 'Peter 7' was listed on the 1950 instrumentation facility inventory, but the target array was not installed until 23 September 1961. An undated facility description lists a cinetheodolite utility building (USAF Building No. 1135, Army No. 29730), a temporary open generator shelter (unnumbered), a latrine (No. H-4261), and the target pole array. [37,38] A 1963 photo shows the building, instrument stand, site name, and the open generator shelter (see Figure 57). The cinetheodolite structure and generator shed were apparently dismantled, since very little superstructure material remains.

Table 13
Bern Site Target Poles

Target No.	Poles	Azimuth	Distance
1	2	308°14'46"	2,500'
2	1	353°14'05"	2,520'
3	1	38°14'41"	2,500'
4	1	83°14'43"	2,560'
5	1	133°15'27"	2,560'
6	1	173°14'20"	2,560'
7	1	218°15'15"	2,520'
8	1	263°13'28"	2,520'

Features 121 and 144 (MTSA: HAR-041, LA 104274)

Two fixed camera ground stations were identified as features within the MTSA (HAR-041/LA 104274) during the documentation of that site by Human Systems Research. [39] The features are located on a flat alluvial plain at an elevation of approximately 4,085 feet ASL (see Figure 4).

Feature 121 consists of a cinetheodolite shelter pad and two associated features overlooking the edge of Lost River just southwest of the Aerobee launch complex (Figure 69, see Figure 32). The cinetheodolite shelter pad has a 1' 9" diameter, 4' 5" tall camera stand with three electrical outlets beside it. The camera stand pad has a wooden 2" x 4" frame and lumber is collapsed around it. A 3' square x 1' 9" deep conduit pit is attached to the shelter pad and 2" x 4" lumber lines a gravel path 27 feet from the pad to the six concrete pad footings for the generator shed. The 1' square concrete footings are in a 12' 6" x 12' area. Wire nails are scattered between the pads. The shelter and shed foundations are within a 115' x 80' gravel area. Northwest of the camera pad are a short wooden power pole and a 9' x 6' x 2' depression which may be the latrine pit. Two tags with "+2 AP" and "CA-3 152-165 T-9" on them were found by the poles. A gravel road runs south of the features towards the Aerobee launch facility.

Feature 144 consists of a cinetheodolite shelter pad and two associated features southeast of the

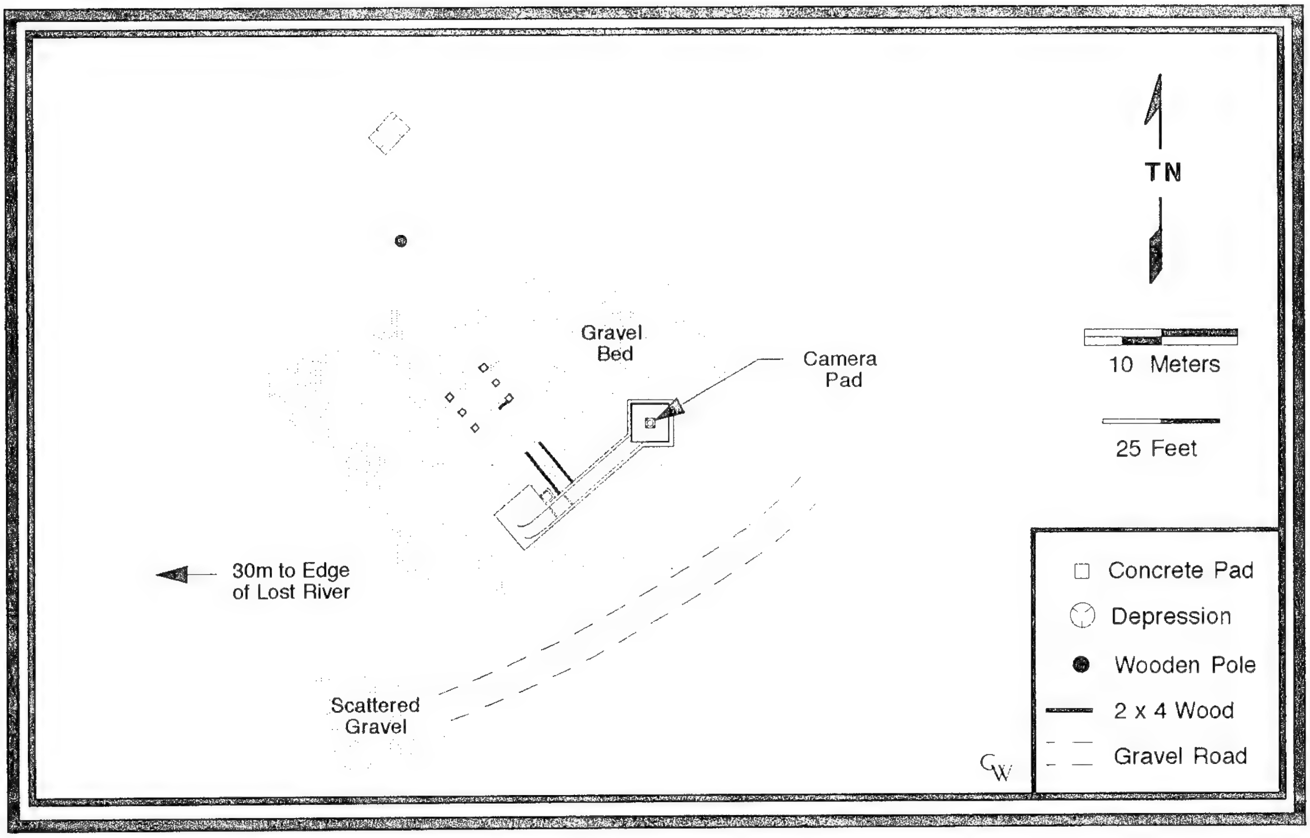


Figure 69. Feature 121 (MTSA: HAR-041, LA 104274) fixed camera ground station map.

GAPA and NATIV launch complexes (Figure 70). The cinetheodolite shelter has an intact 1' 9" diameter x 4' 4" tall camera stand with the wooden 2" x 4" frame and collapsed lumber around it, and 2" x 4" lumber lines a gravel path 27 feet from the pad to an overturned 50-gallon trash barrel. The six concrete pad footings for the generator shed are located adjacent to the utility pad. The 1' square concrete footings are in a 12' 6" x 12' area. A scatter of wire nails is between the pads. Southwest of the camera pad is a short wooden pole with a buried cable sign on it, and a metal frame is to the northeast. A gravel road runs south of the features towards the main HAFB road.

There is no evidence of the target pole array around either facility, although numerous telephone poles without targets are in the vicinity. Some of these may have been associated with one or the other of the ground stations. The facility names of the features have not been identified, although Feature 121 may be 'Peter 3' and Feature 144 might be 'Peter 4' or 'Peter 5'. These Peter facilities are illustrated in approximately the correct locations on an undated instrumentation map. [40]

Both features have been used for recent military maneuvers, indicated by the numerous M-16 and M-60 cartridges in the vicinity. There is no evidence of a rock aligned facility name at either feature, and only Feature 121 has a possible latrine pit. Feature 144 has had a buried cable run through it, disturbing the gravel pad. The ground stations may have been built prior to 1949 when military personnel operated instrumentation stations. 'Peter 3' and 'Peter 5' are both listed on the 1950 instrumentation facility inventory. [41]

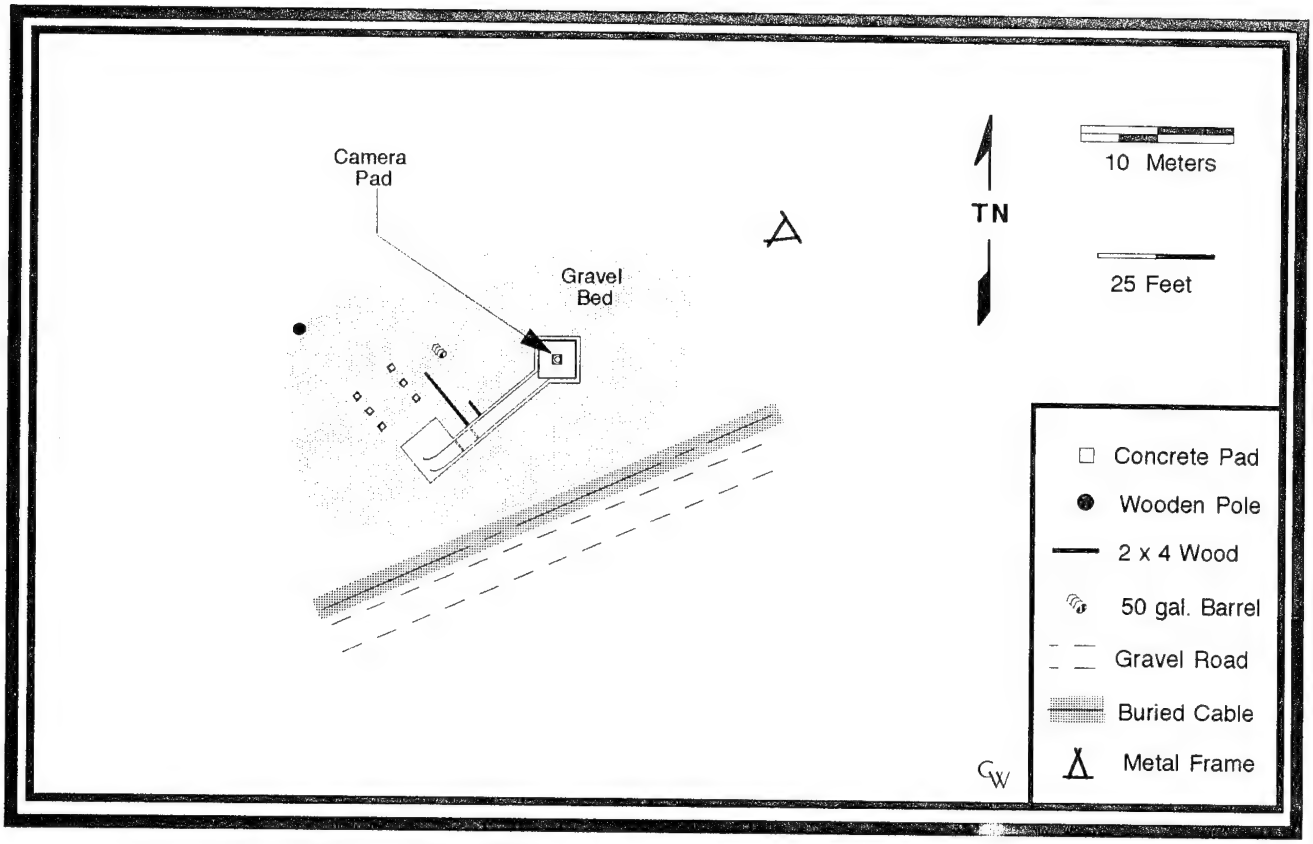


Figure 70. Feature 144 (MTSA: HAR-041, LA 104274) fixed camera ground station map.

AEROMEDICAL RESEARCH

Aeromedical research was conducted on HAFB mainly to determine the affects of high altitude flight on people. Much of this research was in support of the missile and rocket test programs, working towards sending manned vehicles into space. Four programs are discussed here, including the Aeromedical Research Laboratory, Daisy Test Track, Project Manhigh, and Project Excelsior.

The Aeromedical Research Laboratory (ARL) was created in 1951 and included the Holloman Zoo for housing the research animals used as subjects for rocket and balloon projects, subgravity, escape physiology, and automotive crash testing. The lab also operated testing devices such as the Bopper Sled and Swing Seat. The 240 foot long Daisy Track, part of the ARL, was in operation between 1955 and the early 1980s for deceleration tests using both animal and human subjects on the sled runs. Project Excelsior, administered by HAFB in 1959, utilized balloons and C-97s to drop dummies and human subjects for testing ejection seats and parachutes. Project Manhigh used balloons to test the effect of high altitudes on humans. Although only one flight occurred on HAFB in 1958, it was a major contribution towards learning the affects of space on pilots.

No archaeological or architectural work was completed on the aeromedical research facilities. The ARL is now the Primate Research Laboratory (PRL). Building 1264 within that facility, and the buildings in PRL's Biocontainment area, the site of the Daisy Track, are presently scheduled for architectural assessment. The Daisy Track is currently housed at the ISHF, and there are no physical remains from projects Excelsior and Manhigh.

Aeromedical Research Laboratory

One of the principal organizations in the United States Air Force's 'Man In Space' program was AFMDC's Aeromedical Research Laboratory at HAFB. The organization made important contributions in the areas of space biology and biodynamics. This first work in space biology started at WSPG in southern New Mexico in 1946 when fruit flies, fungus spores, and small mammals were launched into the earth's upper atmosphere in rockets. These early experiments were sponsored by the Aeromedical Laboratory at Wright Field (later Wright-Patterson AFB) in Ohio.

HAFB became the launch site for upper atmosphere research in 1950 when balloons, designed to study the biological effects of cosmic radiation, were sent aloft. Then, in 1952 and 1953, three Aerobee rocket flights were conducted to explore the effects of weightlessness on mice and monkeys. The Aeromedical Field Laboratory (AFL) was created in 1951 as a support facility for Wright Field Projects. In January 1953, the AFL was assigned to HAFB as a unit of the Air Force Missile Development Center. [1] On 1 December 1961, the organization was designated the 6571st Aeromedical Research Laboratory and on 1 January 1962, the Laboratory was placed under the Aerospace Medical Division for administrative purposes. [2] The AFL/ARL stayed in existence for nearly 10 years and before being

disbanded. During its existence, many experiments were carried out which contributed greatly to both the advent of 'Man in Space' and the general public. All military aircrews benefited from their work and the number of lives saved can not be truly calculated.

The assignment of Major (Dr. and later Lieutenant Colonel) David G. Simons and Lieutenant Colonel (Dr. and later Colonel) John P. Stapp greatly aided the evolution of the Laboratory. Both men were intent on building up the Holloman mission in biomedical sciences and were destined to make a lasting impression on not only the Laboratory, but the Missile Development Center as well. Dr. Simons arrived in January 1953 and Dr. Stapp in April 1953. [3] The arrival of Dr. Stapp also meant the laboratory had added another research project, Biophysics of Abrupt Deceleration, to its growing list of responsibilities. Later, this project broadened into Biodynamics of Human Factors in Aviation, which included tolerance to impact forces, total pressure change, abrupt windblast, aircraft crash forces, and automotive crash forces. In 1958 the Biodynamics of Human Factors project was rewritten to bring it in line with the emphasis on space exploration. [4]

Holloman Zoo

A number of specialized test facilities were created at HAFB specifically for the ARL, or under the jurisdiction of some other unit but available for biomedical research. One of these was the 'Holloman Zoo' of test animals. This zoo, located adjacent to Building 1264 in the current Primate Research Lab compound (see Figure 4), was unique since it was always operated by trained ARL personnel. The animals in the zoo included mice, hamsters, dogs, and cats. Later, chimpanzees, hogs and bears joined the zoo. This facility became part of the AFL in August 1959 and remained part of the 6571st ARL until 30 June 1971, when the operation became part of the Albany Medical College. In 1980 the Primate Research Facility, as the zoo came to be known, was transferred to New Mexico State University's Primate Research Institute. Finally, on 1 July 1993, management of the facility was assumed by The Coulston Foundation.

Planning for a Chimpanzee Consortium resulted in the award of a contract in March 1965. This Consortium was an outdoor area, 1,300 feet in diameter and surrounded by a water-filled moat 18 feet wide and 4 feet deep (Figure 71). Twenty feet beyond the moat was an electrified 10 foot tall cyclone fence. The Consortium was to have a 3,200 SF observation and treatment building on the north side of the moat perimeter. Landscaping work for this Consortium started on 29 June 1965. [5] Unfortunately, the chimpanzees proved to be destructive to the vegetation planted inside the moat-surrounded area so the area was never relandscaped. Later they learned how to swim the moat and were able to escape into the desert.

Probably two of the most famous residents of the zoo were the two "Chimpnauts," HAM and Enos (Figure 72). HAM, which stood for Holloman Aero Med, was initially named Chang. [6] The chimpanzee was trained at the 6571st ARL for Project Mercury. On 31 January 1961, HAM completed a 155-mile-high suborbital flight 420 miles down the Atlantic Missile Range. He preceded the Mercury astro-

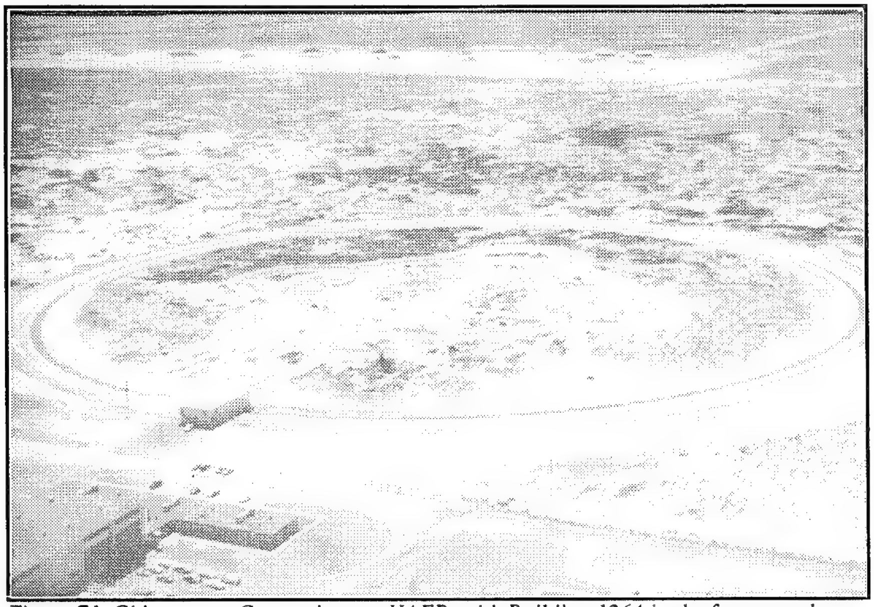


Figure 71. Chimpanzee Consortium at HAFB, with Building 1264 in the foreground, ca. 1966 (Space Center archives).

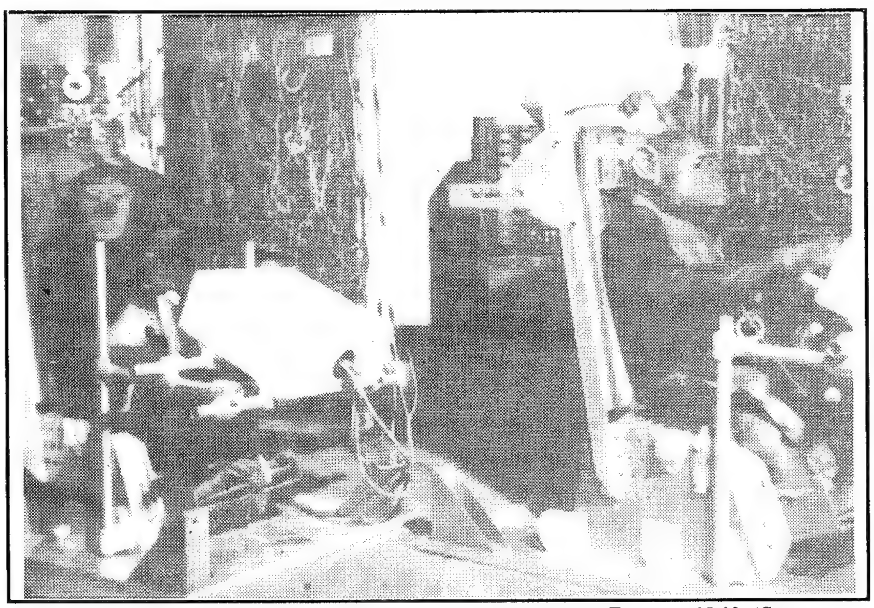


Figure 72. HAM and Enos in Space Trainers at the Holloman Zoo, ca. 1960 (Space Center archives).

nauts' into space and, during his sixteen-minute flight, reached a speed of 5,800 mph. [7] Enos was the second Project Mercury chimpanzee sent into space, where he made a flight of two orbits of the earth on 29 November 1961 (Figure 73). Enos preceded the Mercury astronauts' orbital flight and spent 183 minutes in weightlessness at a perigee, the closest point of approach to earth from orbit, of 99 miles and an apogee, the farthest point from earth in orbit, of 146 miles. [8] Enos died of non-space related causes in November 1962 and HAM was transferred to the National Zoo in Washington, DC, in April 1965.

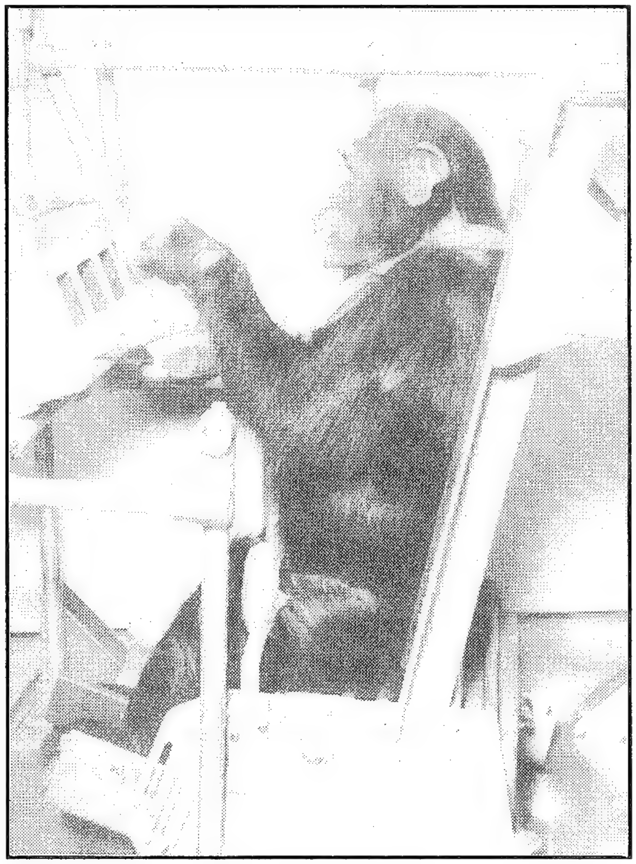


Figure 73. Enos on Space Trainer at the Holloman Zoo, ca. 1960 (Space Center archives).

Four bears arrived at HAFB from the New York Catskill Game Farm in November 1957 to be used as subjects in impact forces testing. Their arrival was accompanied by a wave of unwelcome publicity. The story of these bears was played up in the national press because it came just a few weeks after the Russians launched a dog-carrying satellite. This inspired a rumor that the United States Air Force was attempting to outdo the Russians by launching a bear-carrying satellite. [9]

A wide variety of animals was required for research at HAFB because no one animal was suitable for all test purposes. Once, when questioned by a Congressional subcommittee, Dr. Stapp remarked:

> "You wonder why I use hogs —
> hogs and chimpanzees? Well
> man is somewhere between the
> hog and the chimpanzee. Some
> people are more like hogs; others
> are more like chimpanzees." [10]

The ARL was the only Air Force agency with bears, hogs, and chimpanzees. Other Air Force agencies had small laboratory animals, but none the size of those at HAFB. The laboratory had the equipment, accommodations, and technical expertise in maintaining its zoo. Not only did the laboratory furnish animals for its own needs, but it supported other Air Force scientists located away from HAFB. [11]

Rockets and Balloons

Holloman's participation in aeromedical activities at first consisted of rendering support services for V-2 launches at WSMR. The first biomedical experiment started on 17 December 1946 with a V-2 launch. The goal of the experiment was to expose fungus spores to cosmic radiation by rocketing them to the extreme upper limits of the atmosphere. The experiment was a failure because the payload containing the spores was not recovered. In 1947, a container of fruit flies was rocketed to an altitude of 106 miles. The payload was successfully parachuted back to earth and the flies were recovered alive and in apparent good health. [12]

The AFL was offered some space in the V-2 rocket 'Blossom' test series and proceeded to make plans to send monkeys into space in pressurized capsules. On 11 June 1948, a nine-pound monkey named Albert went aloft. The mission, named Albert 1 after the monkey, was a failure since instrumentation for transmitting respiratory rate apparently failed prior to launch. The parachute on the capsule also malfunctioned and the monkey expired. However, the onboard recorder, which was recovered, indicated the monkey died as a result of a difficulty in breathing prior to launch. [13]

Albert II was launched on a V-2 rocket on 14 June 1949. Once again there was a recovery parachute failure and the monkey died. However, the recovered data recorder showed the monkey had lived through the flight to an altitude of 83 miles. The third attempt, on 16 September 1949, was a total failure. The V-2 rocket blew up seconds after leaving the launch pad. Attempt number four, on 8 December 1949, was a carbon copy of the second flight. The fifth and final V-2 aeromedical flight took place on 31 August 1950. The passenger on this mission was not a monkey, but a mouse. The mouse was photographed with a camera to see if muscular coordination was retained during the flight, and the resultant photographs showed that muscle coordination was normal. They further showed the mouse was unaffected by the lack of gravity and it no longer had a preference as to which way was up. [14]

The aeromedical operations were then transferred from WSMR to HAFB and the new Aerobee rocket program. But bad luck continued to plague the program. During the first Aerobee launch of 18 April 1951, data was recorded, but once again there was a recovery parachute failure. Then, on 20 September 1951, a monkey and eleven mice, cosmic radiation test subjects, roared up to an altitude of 236,000 feet in the nose of an Aerobee. This time the recovery parachute functioned properly and the nose was recovered. Recovery, however, was delayed because the precise impact point could not be immediately located, and the monkey and two mice died of heat prostration several hours after the capsule was found and opened.

Finally, on 21 May 1952, two monkeys and two mice were lifted to an altitude of 36 miles and recovered successfully (Figure 74). Data from both the flight and the postflight physical examination showed they had experienced no ill effects. [15]

The V-2 and Aerobee flights brought complaints from animal lovers around the world and also brought a large number of offers from people who wished to volunteer as subjects on the next rocket launch. Volunteer letters were dutifully answered and the offers rejected on technical grounds. [16]

In addition to rocket tests, there were aeromedical balloon flights. The first of these balloon flights took place on 29 August 1950 from the White Sands National Monument picnic area, about 10 miles south of HAFB. There was no test subject on this flight since it was a practice run using a polyethylene balloon. The balloon went to an altitude of somewhere between 500 to 1,000 feet and then descended to a point about one-half mile from the launch point. A second flight the same day was classified a success when the balloon went to an altitude of 67,000 feet. The first animal attempt, on the third flight, took place on 8 September 1950. The balloon reached an altitude of 47,000 feet. However, all the mice were lost when the capsule depressurized. Flight number four, on 16 September 1950, was an equipment-only flight. Success was achieved with the fifth flight, on 28 September 1950 when a balloon went to an altitude of 97,000 feet. Of the eight mice on board, one died after the flight. It was determined that death was due to pulmonary inflammation and not because of cosmic radiation or the affects of the flight. [17] Balloon test flights continued with mice, hamsters, cats, dogs, and fruit flies as passengers. Altitudes of 90,000 to 100,000 feet were achieved and durations of up to 28 hours were attained. Not all missions were successful, however. On about half the flights there was either balloon failure or equipment trouble. Delays in recovery of the payload also contributed to the death of test subjects. [18]

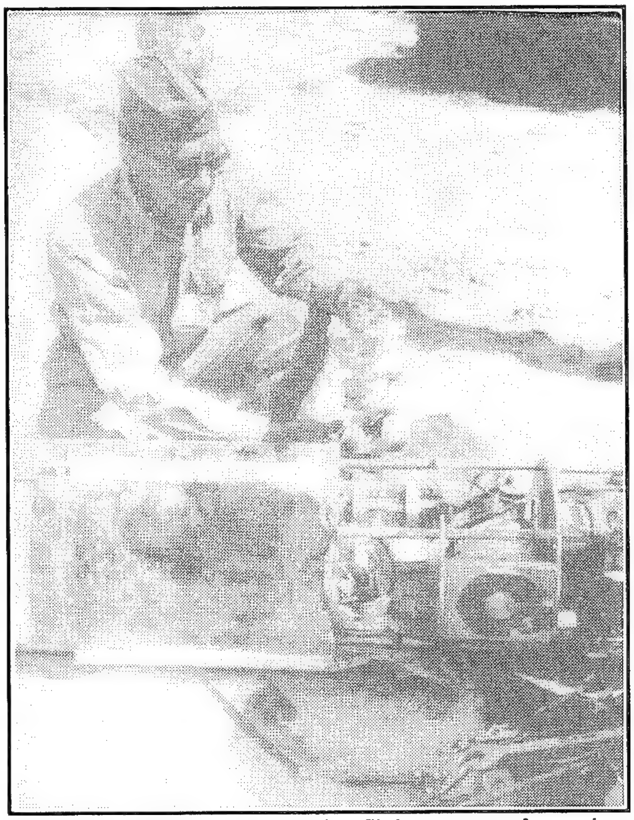


Figure 74. First successful Aerobee flight recovery of a monkey at HAFB, 21 May 1952 (Space Center archives).

AFL balloon flights achieved greater success with the advent of technological developments, such as the perfection of radio command ‘cut-down.’ The ‘cut-down’ was an explosive charge that separated the balloon from the payload. Prior to this development, a timer had been used which might let the capsule down in a thunderstorm or in an inaccessible area. Tracking and recovery techniques were improved by the use of a battery-powered tracking beacon installed in the capsule. The balloons themselves were improved, becoming larger, with up to a two-million cubic feet capacity, and better constructed.

In spite of improvements in technology, there was one area that always presented problems: human error. A flight was started at HAFB on 13 February 1953 with the objective of exposing hamsters to the effects of radiation at an altitude of 90,000 feet for a long period of time. The balloon evaded tracking crews, but the capsule landed the next day near Whiting Naval Air Station in Florida, where it was recovered. Naval authorities sent a teletypewriter message to the AFL asking what should be done with

the capsule. The message was delivered six days later, which was a record in itself considering the inefficient internal distribution system at the AFMDC. When the message finally was received, HAFB researchers made a quick telephone call to Florida and instructed personnel there to open the capsule. All seven hamsters were still alive, although one died the next day and another was later cannibalized by his fellows. [19]

Launches for further cosmic radiation studies were transferred to facilities at higher latitudes. The first north latitude flight was on 26 March 1953 from Tillamook, Oregon. A series of flights ensued, including four flights from Great Falls AFB, Montana between June and July 1953, five flights from Pierre, South Dakota between October and November 1953, and eight flights from Sault Sainte Marie, Michigan in the first part of 1954. Passengers ranged from radish seeds to monkeys. [20] On 19 July 1959, a balloon launched from Flemming Field, South Saint Paul, Minnesota reached at altitude of 126,000 feet. This was a record not only for the AFL, but for polyethylene balloons in general. [21]

Research into cosmic radiation continued, but as 'Man in Space' programs increased in importance, the unmanned balloon flights decreased in importance. This was further amplified by findings which were announced in an August 1955 Alamogordo Daily News article titled "HADC Studies Banish Fears of Cosmic Radiation." [22]

Subgravity

Although the V-2 and Aerobee flights furnished some information about subgravity and zero-gravity, longer duration test exposures were desired. In May 1950, two former German scientists, Doctors Fritz and Heinz Haber, delivered a paper in which they explained how to achieve over 30 seconds of subgravity in aircraft flight. The method was to fly the plane in a parabolic arc, or 'Keplerian' trajectory, where centrifugal force would exactly offset the downward pull of gravity. [23]

Early tests of the Keplerian trajectory were conducted at Edwards AFB in California and at Wright Field in Ohio. None of these early experiments achieved more than a few seconds of true zero-gravity. However, the total subgravity trajectories were reasonably close to the scientists' predictions. [24] Prior to 1954, the sum total of aircraft subgravity experiments was small, but there were enough to allow for tentative conclusions. In September 1954, T-33 flights were conducted to evaluate problems with parabolic subgravity trajectories. Early in 1955, flights were made in an F-89 primarily to evaluate techniques and instrumentation. [25]

The subgravity and zero-gravity program intensified with the assignment of Captain Grover J. D. Schock to HAFB on 1 July 1957. He was awarded the first Doctor of Philosophy degree in space physiology because of his contributions. Captain Schock started F-94C subgravity flights from HAFB in the fall of 1955. These flights gave thirty seconds of subgravity, and more than one run could be accomplished per flight. The actual zero-gravity time was a maximum of twenty-two seconds. This, however, was not continuous, but fluctuated close to zero-gravity in minute fractions. [26]

Aircraft instrumentation was a problem. A golf ball suspended on a string in front of the pilot, the

only instrumentation available at the time, was not good enough. Not only was it affected by slight breezes from the cockpit environmental control system, but slight changes in positive or negative gravitational force could cause the pilot to overcorrect and negate a portion of the test. A combination of accelerometers that relayed visual information to the pilot were added to resolve this problem. In addition to instrumentation, subgravity and zero-gravity created aircraft problems such as loss of oil pressure, loss of hydraulic fluid, and sticking trim tab motors. During these tests, it was also discovered that the standard microphone could not be used to transmit clear messages during subgravity portions of the mission. The problem was researched and a new microphone was developed which, it was felt, would be applicable to future space vehicles and space missions. [27]

Human reactions to the tests varied. Some subjects called the experience enjoyable, while others experienced motion sickness with nausea and vomiting. Tests showed that human functions in subgravity were not seriously impaired, provided there was a visual frame of reference and no motion sickness. Eating in subgravity could be accomplished if the subject chewed the food well, and drinking was found to require the use of a squeeze bottle. [28]

Tests were expanded to include subgravity after exposure to a force of 4 to 5 Gs. Cats were used in the test program because they are renowned for their ability to land on their feet. Once again, tests confirmed the critical importance of visual orientation. [29] Another way to simulate subgravity was total immersion in water. The human reactions to that test was similar to those in a subgravity state. In the spring of 1957, tests were conducted at the Young Men's Christian Association swimming pool in El Paso, Texas. The subjects were placed in a rotating seat in eight feet of water, and were blindfolded to remove visual references. Later that same year, tests were conducted in the swimming pool at the New Mexico School for the Visually Handicapped in Alamogordo, New Mexico. These tests once again showed the importance of visual orientation, because a blindfolded subject could be tilted as much as twenty-two degrees before perceiving the tilt. [30]

Unfortunately, the summer of 1957 (first quarter of FY 1958 according to the fiscal year breakdown of that time) saw the inauguration of an Air Force austerity drive which dealt a setback to the program. Efforts which cost money were ordered to cease immediately, eliminating the F-94C flight program. The appearance of Russian satellites changed the financial outlook and austerity was abandoned. By the start of 1958, the program was back in full swing, but lost time could not be regained. [31] Later experiments were carried out using other, more advanced aircraft such as the F-100 and F-104 fighters, the C-131, and the KC-135. Mercury astronaut candidates experienced the Keplerian trajectory in a modified C-131, which was appropriately named "How High The Moon." [32]

Escape Physiology

Escaping from a damaged aircraft was relatively simple in the early days of aviation. All the pilot had to do was unfasten his safety belt and dive over the side of the open cockpit. Later, when pilots found themselves in the completely enclosed cockpits of more advanced aircraft, escape became more

difficult. The canopy had to be cranked open or slid back, and the safety belt and shoulder harness had to be unfastened before the flier could exit his damaged aircraft. The effect on the human body from windblast or mechanical forces (centrifugal or centripetal) were at times so great that escape became more difficult. The advent of high-speed, jet-powered aircraft created an escape problem of imposing magnitude. The effects of the ejection force, windblast, and wind-drag deceleration, as well as tumbling and spinning, all had to be evaluated.[33]

Early experiments in deceleration had been conducted on the 2,000 foot long test track at Edwards AFB in California, but these tests had drawbacks. The Edwards AFB track used mechanical friction brakes which did not permit the desired high deceleration force or a wide range of duration and rate of onset. The HAFB High Speed Test Track, which was 3,500 feet long at that time, used a water brake which would meet the desired test parameters. When Dr. John P. Stapp was transferred from Edwards to HAFB, he continued his research using the HSTT at his new base.[34]

A rocket sled, named Sonic Wind I, was specially constructed by Northrop Aircraft Corporation for Dr. Stapp's tests. The first practice run of this sled was accomplished on 23 November 1953. On 28 January 1954, the sled was used with a chimpanzee subject, and on 17 March 1954 Headquarters, Air Research and Development Command, granted permission for sled runs with human subjects. Accordingly, on 19 March 1954, Dr. Stapp took his first ride on Sonic Wind I. He sustained a linear force of 15 G for a duration of 0.6 seconds and reached a peak velocity of 615 feet per second and 22 G deceleration force. On 22 August 1954, Dr. Stapp made his second run on Sonic Wind I wearing a special helmet. This test, involving an abrupt windblast experiment which simulated the effect of jettisoning an aircraft canopy in flight, was accomplished by opening doors on the front of the sled. Dr. Stapp sustained minor injury from flapping clothes and windblown grains of sand. Including the rides on sleds at Edwards AFB, Dr. Stapp by then had a total of 28 rocket sled rides.[35]

On 10 December 1954, Dr. Stapp rode Sonic Wind I to a maximum speed of 937 feet per second, which translates to 638.86 mph or Mach 0.9 (Figure 75). During this run, the sled overtook and passed a T-33 aircraft being flown by Captain (later Colonel) J. W. Kittinger, Jr., the future pilot of the Manhigh I balloon. Dr. Stapp experienced a windblast of 7.7 pounds per square inch, or over 1,100 pounds per square foot, and the water brake deceleration exposed him to a force of 43 G. This jolt could be compared with what an automobile driver would experience crashing into a solid brick wall at 120 miles per hour.[36]

Dr. Stapp's sled run provided valuable data and proved that humans could survive windblast at over 600 mph, or equivalent to Mach 1.6 at an altitude of 40,000 feet. His ride also earned him renown as 'the fastest man on earth.' His portrait appeared on the cover of Time magazine, he appeared on television shows, and he was the requested speaker at innumerable gatherings. Because of all this publicity, it quite naturally became nationwide news when, according to the 9 March 1956, issue of the Alamogordo Daily News, 'the fastest man' was cited by the Alamogordo, New Mexico, police for driving his car 40 mph in a 25 mph zone. However, the judge before whom Stapp appeared diverted some of the

Figure 75. Dr. John P. Stapp being strapped into Sonic Wind I on the HAFB High Speed Test Track, 10 December 1954 (Photo courtesy of Northrup Aircraft Corp.).

publicity to himself by dismissing the speeding charge against the famous researcher. The judge then issued a new citation against a fictitious 'Captain Ray Darr,' and paid the fine of $12.50 from his own pocket. [37]

On 14 September 1954, there was a tumbling seat experiment conducted to evaluate tumbling, windblast, and deceleration in combination. A chimpanzee subject was subjected to 105 revolutions per minute by rotation of the seat, sudden windblast by the use of opening doors, and deceleration through the use of the water brake at the end of the sled run. The chimpanzee experienced 45 G deceleration force and survived the ordeal. Since the spinning seat was on a fixed axis and did not wholly simulate free-fall tumbling, the AFL did not continue with the tumbling seat experiments. [38]

Windblast and deceleration studies continued using chimpanzees who experienced combinations of both in differing degrees. In November 1955 and March 1956, chimpanzees were subjected to 80 G deceleration and rates of onset of 4,000 G per second. Tests were halted for about six months while the HSTT was being lengthened to 5,000 feet. The sled also had to be reconstructed following an accident in which it became airborne. Following the modifications, test subjects were exposed to peaks of 247 G deceleration and rates of onset of 16,800 G per second. One test, which was conducted on 2 February 1957, showed that the peak deceleration was one millisecond duration and deceleration was 0.34 seconds. During this test, the chimpanzee was in a seat facing backward. This was in contrast to a test on 12 January 1957 where a chimpanzee was in a forward-facing seat. On this latter run, the chimpanzee was subjected to 233 G for one millisecond, a duration of deceleration of 0.35 seconds, and a rate of onset of 11,000 G per second. The test proved fatal to the chimpanzee. Evaluation of the results of these two tests proved the value of rearward facing seats for survival in the event of an airliner crash. [39]

While the HSTT was being lengthened to 35,000 feet in 1957, tests were transferred to China Lake, California, where the first run was made on 18 February 1957. The chimpanzee in the test was subjected to windblast while traveling at a velocity of 1,945 feet per second, or Mach 1.7. Unfortunately, the headrest failed prior to reaching supersonic speed. This caused a failure of the helmet, which broke the chimpanzee's neck. The test underscored the danger that existed from flailing if the subject was not properly secured. [40]

The next China Lake run was on 27 June 1957. A chimpanzee was subjected to roughly Mach 1.7 with a windblast of 3,500 pounds per square foot. Both the helmet and clothing failed, and forty percent of the chimpanzee's body experienced second and third degree burns. Three guinea pigs also rode the sled during the run. Two of them were fastened to the sled with nylon netting; the third was in a metal container that had several openings, the largest measuring one inch by two inches. The metal container survived the ride, but all three guinea pigs vanished into thin air. [41]

Test personnel felt the burns experienced by the chimpanzee could be prevented with proper clothing. Accordingly, a chimpanzee suit was made of Dacron sail cloth. On 12 March 1957 the suit was tested. Once again, there was a failure of the harness that caused the helmet to fail and the chimpanzee was lost. The remaining two runs of the planned test series were then transferred back to HAFB and the

35,000 foot test track. [42]

Research was conducted in April 1951 on the possibility of remaining fastened to an aircraft ejection seat throughout parachute descent. Subjects were placed in a seat attached to a small plastic balloon. The subject, seat, and balloon were then taken up in the air a short distance, coming down with the balloon acting as a parachute. Impact velocity was increased until it approached that of a standard parachute's landing speed. Volunteers reported some discomfort, but felt the procedure was worth further investigation. These tests, like those of the first AFL balloon flights of August 1950, were launched from the sand dunes of White Sands National Monument. [43]

Project Woosh, a joint project of HAFB and Wright Field, was an evaluation of escape from high-speed aircraft flying at Mach 2, and was supported by the ARL. A chimpanzee was ejected from a specially designed Cherokee missile, which was carried aloft by a modified B-29 and then launched. After acceleration to supersonic speed, the chimpanzee was ejected in an open ejection seat. Two tests were conducted at Edwards AFB and then the program was brought to HAFB because of the superior range instrumentation and the availability of chimpanzee living quarters. Two supersonic tests were conducted at HAFB, one on 21 October 1955 with the chimpanzee being ejected at Mach 1.5, and the other on 3 April 1956 with ejection at Mach 1.4. Neither of the chimpanzees survived the tests because of equipment difficulties such as parachute system or seat failures. However, even failures furnished usable data which led to changes in parachute systems and ejection seats. [44]

Operations for Woosh were then transferred to Hurricane Mesa, Utah, for testing on the Supersonic Military Air Research Track (SMART). This track terminated on the edge of a cliff with the canyon floor 1,500 feet below. In the fall of 1956, a total of five tests at approximately Mach 1.0 were conducted and the chimpanzees were recovered uninjured. In March 1957 another test was accomplished with a 'chimpomorphic' dummy, followed by a test with a live chimpanzee. This latter test was unsuccessful because the sled wrecked. The AFL furnished the chimpanzees for these tests and took an interest in the proceedings. [45]

Investigation of forced landings of F-102 aircraft, for example, indicated that landing occurred with a high angle of attack. When the tail dragged the ground, the pilot was 55 feet away in the nose and anywhere from 18 to 25 feet above the ground. Dragging the tail caused the nose of the aircraft to slam into the ground with a force of about 60 G. The AFL evaluated the F-102 seat, and devised a test that dropped the seat vertically a distance of 70 inches while the sled was being decelerated. The first test in this series took place on 21 April 1955, and involved an anthropomorphic dummy. The dummy was subjected to a peak force of 50 G in a vertical direction and 25 G in a horizontal direction. Later tests were conducted with chimpanzee subjects. This test series ended on 28 June 1955, furnishing data on crash forces and how they could be reduced by means of uplifting shoulder straps and energy-absorbing seat cushions. [46]

Automotive Crash Forces

The Aeromedical Field Laboratory also was heavily engaged in automotive crash force investigations. On 10 March 1955, two dummies were fastened into a 1945 Dodge weapons carrier with lap belts. This un-instrumented vehicle was then crashed into a barrier for the first trial run. The first full scale automobile crash test was conducted on 17 May 1955. Other crashes were staged using both anthropomorphic dummies and animals as test subjects. The vehicles used during these tests were no longer worth repairing, so they were destroyed by crashing them into fixed barriers or other condemned vehicles. Attempts at roll-over crashes were at first unsuccessful, but the technical difficulties were soon overcome and the test methods proved successful. [47]

For sudden stop tests, a metal cable was attached to the frame of a vehicle and the other end fastened to a mechanical snubber which could be adjusted to the desired crash configuration. This stopping device was furnished by General Motors Corporation for the nominal sum of $25. Once the stopping system proved successful, the task scientist, Lieutenant Daniel L. Enfield, rode one of the vehicles during a test. [48]

Ford Motor Company developed an energy absorbing steering wheel, and tests of this device were conducted between August 1955 and June 1956. In December 1955, the AFL tested hydraulic energy absorbing bumpers to determine the reduction in crash forces. Tests showed injuries would be reduced through the use of such devices. The hydraulic energy-absorbing bumper, for example, would absorb as much as 85 percent of the impact forces in a 30 mph collision with a solid, stationary object. [49]

After unwarranted congressional criticism, the Air Force phased out the Automotive Crash Force program in October 1958. People had received the erroneous idea that the Air Force was buying brand new automobiles to destroy in crash tests. Testimony in front of a Congressional Committee proved this was a misconception, but the Air Force decided to get out of the automotive crash business anyway. [50]

Bopper Sled

A test device that figured in the deceleration test program as well as the crash force program was the 'Bopper.' The original version was acquired from Northrop in March 1955 and was replaced by an improved model a year later. Basically, the Bopper consisted of a seat propelled by elastic shock cords along a short, portable stretch of track. It could impart G-forces of short duration with magnitudes, using the 1956 model, of up to 30 G.

Human volunteers were subjected to a force of 12 G while either seated facing forward or backwards. After the Bopper seat came to a halt, the subject was required to unfasten the seat belt and proceed along an aisle to a simulated emergency exit. They were observed to see how quickly and efficiently they could complete this task. Results showed responses after deceleration were better when the subject was in the backward-seated position. Data on G-tolerances with seat belt restraint devices applied to automotive crash research, and data obtained under automotive crash force tests was in turn applied to aircraft crash studies. In 1957, the Bopper was used to evaluate a combination of conventional

lap belt and a single, diagonal strip across the chest and one shoulder. Using a lap belt only, Lieutenant Sidney T. Lewis rode the Bopper to a 27 G stop. He reported some discomfort, but sustained no irreversible injury. [51]

Swing Seat

Still another device used by the AFL was the Swing Seat, a platform with a B-17 seat attached. The platform and seat were raised to the desired drop height by a crane. Deceleration was caused by aircraft cables attached to the back of the seat, and occurred at the precise moment the fall of the swing placed its position perpendicular to the ground. Using this method, the test subject was subjected to a force of up to 23 G, with the peak lasting for one millisecond. The first human to ride the swing seat was Lieutenant Sidney T. Lewis who was followed by many other volunteers. [52]

In addition to humans, hogs were used as test subjects in the swing seat during the automotive crash program. There was a problem in strapping the hogs into the seat because of the physical differences between a hog and a human being. However, this problem was soon overcome. Using the swing seat, the value of the Ford Motor Company energy absorbing steering wheel was tested. It proved to be valuable at impacts of 20 mph. These tests, using hogs, were conducted by the Air Force because the legal and public relations people at Ford Motor Company refused to countenance the use of test animals. Through the use of hogs, it was determined there were definite injuries to the lungs, heart, and abdominal organs at a force of approximately 40 G, which proved lethal. [53] In the course of determining the tolerance to deceleration, different types and styles of lap and seat belts were tested using the swing seat.

Daisy Track

Daisy: Webster's Ninth New Collegiate Dictionary gives various definitions for the word. According to Webster's, a daisy is "a composite plant having a flower head with well-developed ray flowers." Another meaning is that applied to a first-rate person or thing. Nowhere in the dictionary will you find the meaning of the word "daisy" as it was applied to the Daisy Decelerator or, as it came to be called, the Daisy Track. There was a period of time in American history when every red-blooded American male child begged his parents for a certain type of present: a Daisy air rifle. This rifle-like weapon fired a copper or lead sphere, known as a B-B, by pneumatic means. The weapon would be cocked with a lever located behind the trigger. This cocking action compressed air into a storage cylinder and released it directly behind the B-B when the trigger was pulled, creating pneumatic action.

The creation of the Daisy Decelerator can best be attributed to Doctor (Colonel) John P. Stapp. Dr. Stapp said the Daisy was born on 13 May 1953, the date on the Disposition Form he wrote to develop the Track. He envisioned an arrangement of pistons, cylinders, tracks, a sled, and a braking system. This arrangement was to have various ranges of magnitude, duration, and abruptness of G-force upon impact. [54]

The initial design of the 120 foot long track, the sled, and the brake system was accomplished at the Engineering Laboratory at HAFB. Frank Tatsch Construction Company of Silver City, New Mexico, was selected to construct the track, and the contract for the track's braking device went to Service Metals Fabricators Company of Santa Monica, California. The track was installed in what today is the Primate Research Laboratory's biocontainment area, and was first used on 22 September 1955 (Figure 76, see Figure 4). [55] Because of a delay in the design of the pneumatic action air gun, seat ejection catapults provided propulsion for the first tests. Air gun design was completed and fabrication accomplished under contract and was accepted in August 1960. [56] At this time, the name Daisy, which came from the toy air rifle, now truly applied.

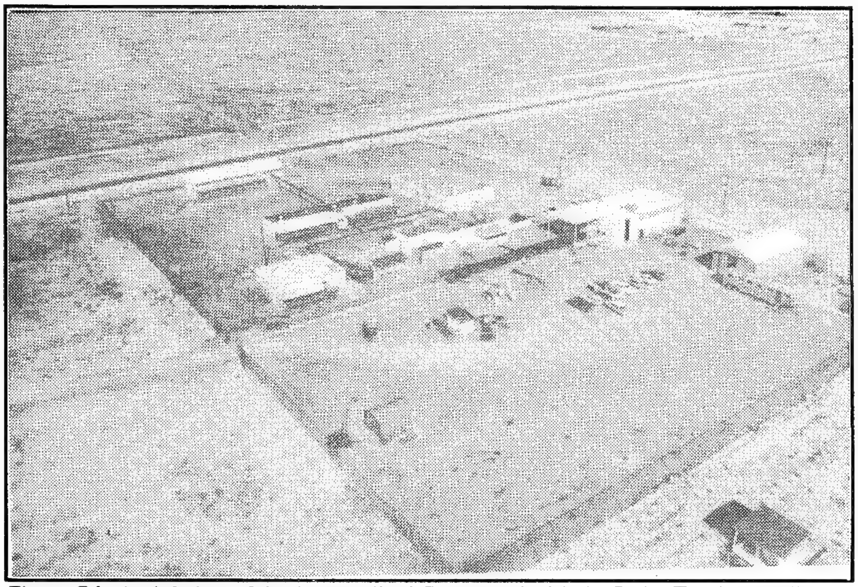


Figure 76. Aerial view of the Aeromedical Compound with the Daisy Track extending from Building 1204 (right center of photo), ca. 1966. The Swing Seat and chimpanzee housing were also located at this facility (Space Center archives).

About the time of the acceptance of the air gun, consideration was given to lengthening the Daisy Decelerator to 240 feet for the purpose of increasing the time interval between acceleration and impact. In February 1961, a contract was awarded for the track extension, which was accepted for operational use in October 1962. [57] The additional length was used only when needed since the original length of the track met the requirements for the majority of the tests. With the extension, and due to increases in the weight of the test sled and a desire for easier programming of the mission profile, a second hydraulic water brake was procured. Water brake No. 1, the primary hydraulic brake, was installed at the 120 foot point and water brake No. 2, the alternate brake, was at the 240 foot point. [58]

The track consisted of two solid steel rails, 3 inches in diameter and set 5 feet apart (centerline to centerline distance). The rails were supported by a welded steel superstructure bolted to a reinforced concrete foundation (Figure 77). The rails were cold-rolled steel for smooth surface finish and close tolerance. Their ends were joined by concentric dowel pins. Lateral alignment was accomplished by tapered wedges and vertical alignment by shims. Alignment was maintained to the degree necessary to produce less than 2 G peak vibrations on a moving sled in the vertical and lateral directions. [59] The track was designed to withstand reactions from the sled equivalent to a static vertical load of 40,000 pounds and a lateral load of 10,000 pounds. Midway down the track there were provisions for mounting a 200,000 pound force hydraulic brake, while a 400,000 pound force hydraulic brake could be mounted at the 'muzzle' end of the track.

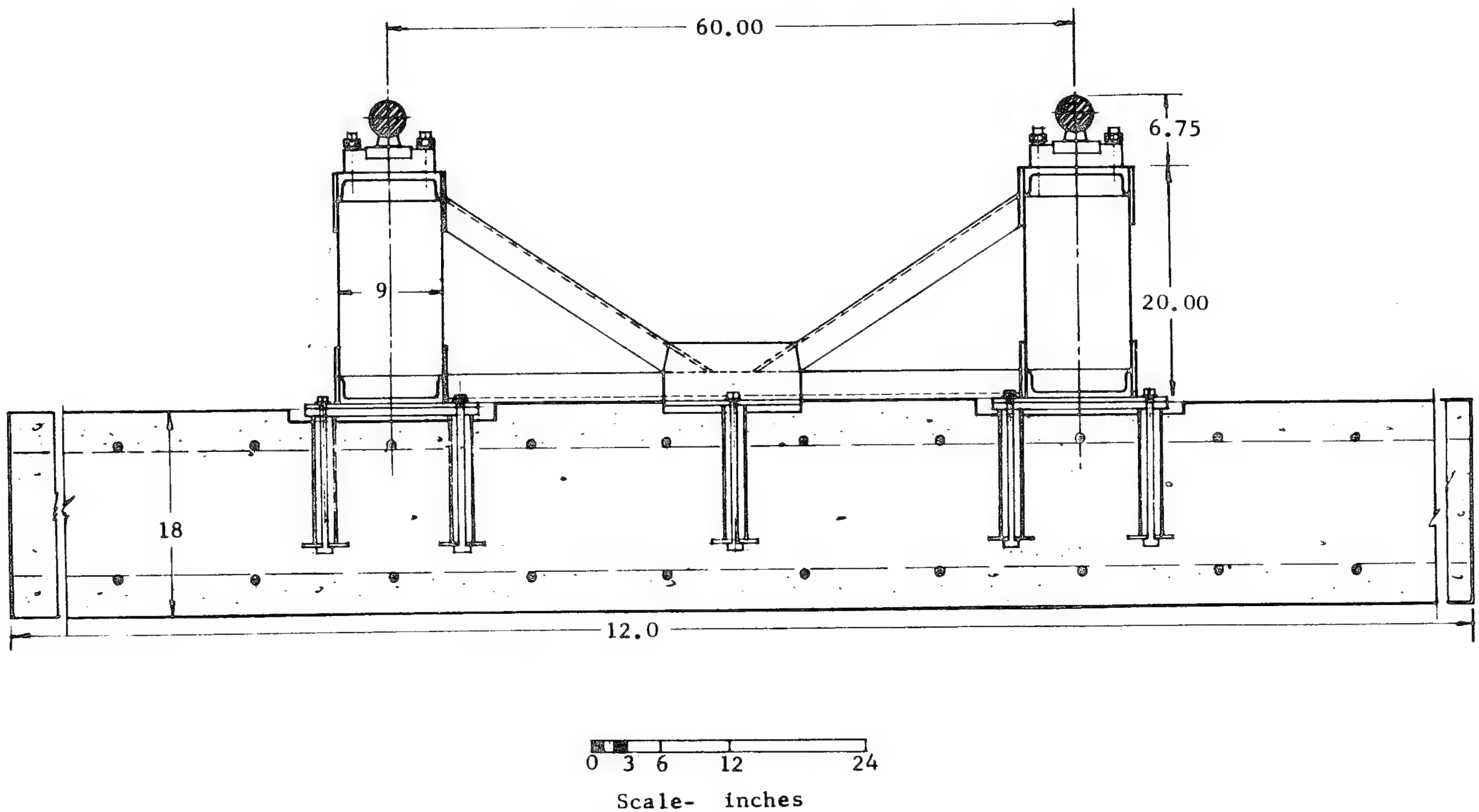


Figure 77. Daisy Test Track cross section (Space Center archives).

The air gun was used to impart sufficient velocity for the sled to accomplish the desired deceleration pattern. It was capable of accelerating sleds weighing from 250 to 2,000 pounds to predetermined velocities between 30 to 175 feet per second with an onset acceleration of 500 G/second. The error in sled velocity with the air gun system was within plus or minus five percent. Velocities less than 30 feet per second could be obtained, but the margin for error was larger than five percent. When the sled weight was increased beyond 2,000 pounds, it could not be accelerated to maximum velocity. [60]

Compressed air, which at the time of the installation and certification of the air gun enabled the sled to be propelled at a cost of five cents per run, drove a hollow piston forward to launch the sled (Figures 78 & 79).[61] The forward end of the thrust piston was attached to a bolster which rested on the track. The sled was in direct contact with this bolster until maximum velocity was obtained. When maximum velocity was reached, the thrust piston was brought to rest by a water brake while the sled continued down the track. [62]

The air storage tank held a volume of 80 cubic feet, while the hollow thrust piston and housing held slightly more than 20 cubic feet. This gave a total enclosed volume for the entire pneumatic system of just over 100 cubic feet. A two-stage air compressor was driven by a 40 horsepower motor and could pressurize the storage tank to 650 pounds per square inch (gauge) pressure in about 75 minutes. A gate valve assembly between the air reservoir and the thrust piston assembly allowed residual air to be retained in the storage tank between cycles, thus reducing the time required to repressurize the system for the succeeding test runs.

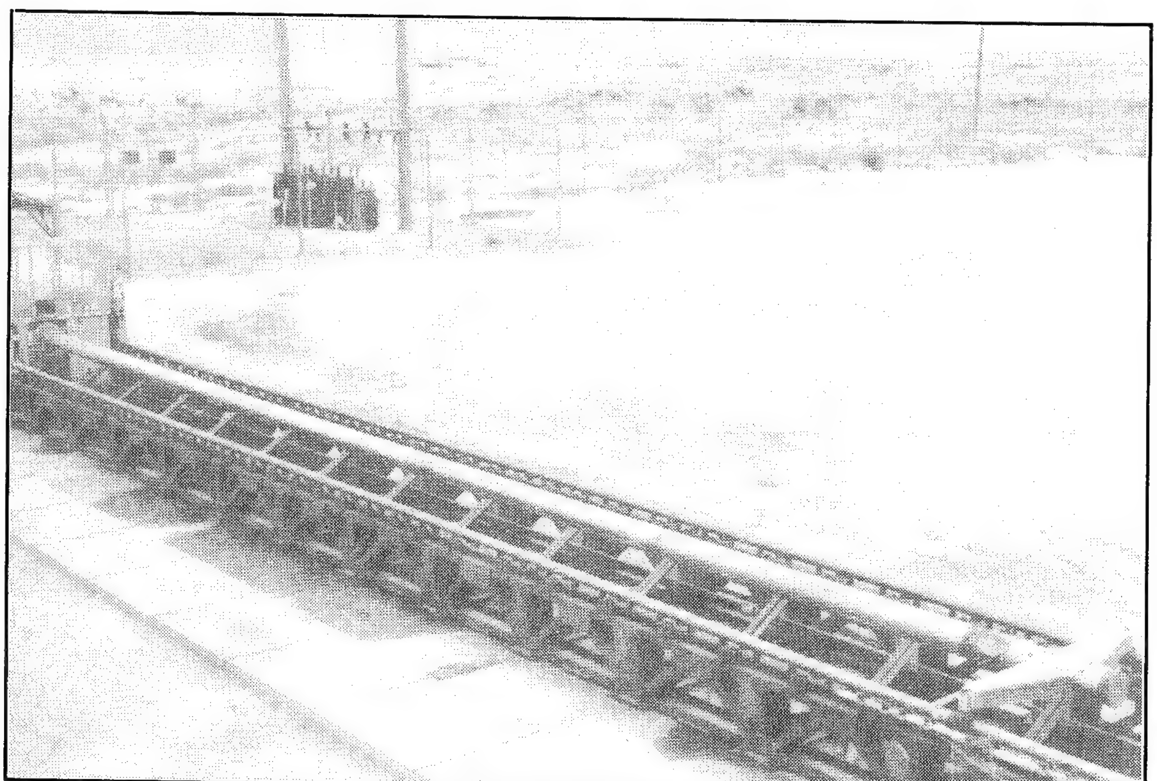


Figure 78. Airgun piston extended full length, before construction of the building to house it, ca. 1963 (Space Center archives).

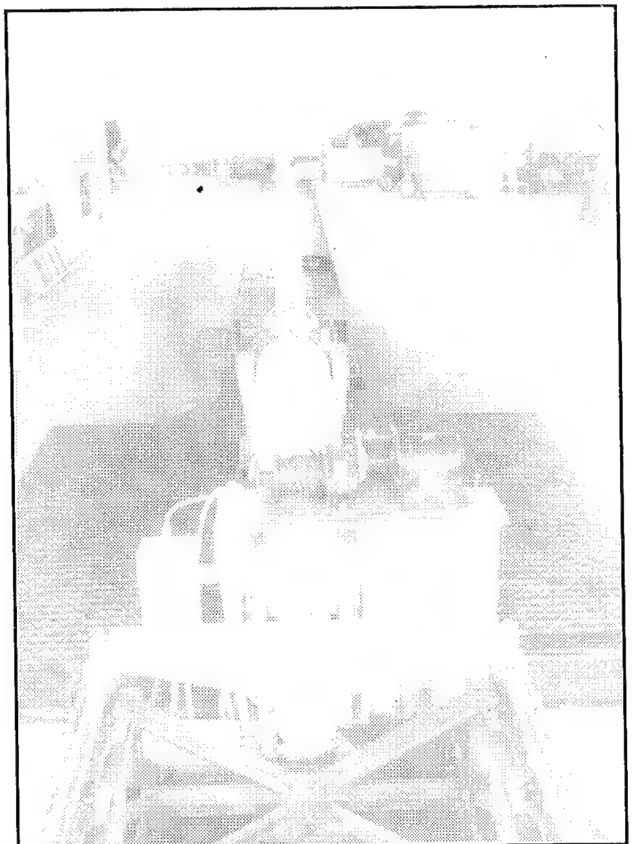


Figure 79. Interior of Airgun building (Building 1204) showing piston, compressor, and plumbing, ca. 1966 (Space Center archives).

The thrust piston consisted of a hollow aluminum tube, about 60 feet long and with an 8 inch outside diameter. Of this length, about 10 feet were needed because of the space required for the thrust piston brake, and about 8 feet were required to decelerate the thrust piston. This left 42 feet of effective length to accelerate the sled, which was constant for all tests. Velocity variations were achieved by changing pressure in the system. At the end of its travel, the thrust piston was stopped by an air gun piston brake.[63]

After the thrust piston had stopped, the sled continued to coast down the remaining portion of the Daisy Track. At first, the braking system consisted of lead cones. However, this proved unsatisfactory and the system was changed to allow the use of a water brake. The front of the sled contained a piston which was 52 inches long, 6 inches in diameter, and capable of sustaining a maximum load of 900,000 pounds. This piston engaged a stationary hydraulic cylinder at the end of the track. As mentioned above, there were two different hydraulic brakes used to stop the sled. Brake No. 1 was designed to produce a 200,000 pound force on the 6 inch in diameter piston (Figure 80). The main element of this brake was the braking cylinder, which consisted of a rectangular block of steel, bored so the piston on the sled could enter. Radial holes were drilled in the upper half of the cylinder and were threaded to accept orifice plugs. During operation, the front end of the cylinder was closed by a thin frangible diaphragm and the cylinder filled with water. When the piston entered the cylinder, it broke the diaphragm and attempted to force the water through the brake orifice plugs. The resistance of these orifices created back pressure, which acted on the piston and decelerated the sled. Orifice sizes were calculated using the First Law of Thermodynamics as applied to a steady flow process, and the result was that braking force or deceleration was tightly controlled.

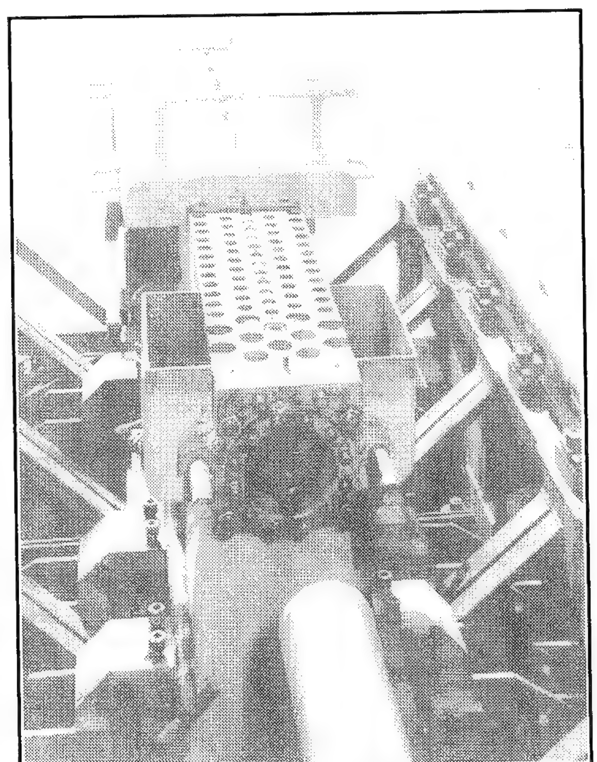


Figure 80. Water brake No. 1, the primary hydraulic brake at the 120 foot point of the track, ca. 1959 (Space Center archives).

Brake No. 2, considered an alternate, utilized the same principal of hydraulics and thermodynamics, but the brake was capable of producing deceleration forces up to 400,000 pounds (Figure 81). Using Brake No. 2 required installation of a 'shaped probe' on the front of the sled, a design in which water was passed through an orifice formed by the sharp edge of the braking cylinder and the probe (Figure 82). Probe cross-section was varied in order to change the annular orifice area. To keep from maintaining a large supply of different sized probes for different mission requirements, the probe was designed so its effective cross sectional area could be varied by orifice plates set in longitudinal grooves cut along its sides. This enabled the orifice area to be easily varied by selection and location of the proper orifice plate on the probe. Sixteen 'pop-off' valves were provided at the end of the steel cylinder to discharge the water at a constant pressure. These 'pop-off' valves were pre-loaded to the desired pressure for opening, and the Air Force kept a large number as a safety factor in the event of a malfunction of one or more of the valves. [64]

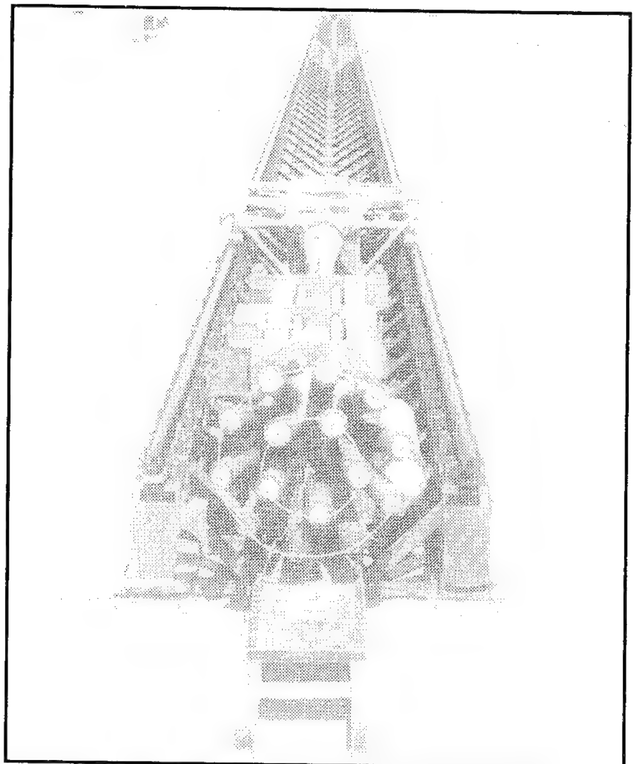


Figure 81. Daisy Track decelerator looking from Brake No. 2, the alternate, towards airgun, ca. 1962 (Space Center archives).

From Safety Test Reports of tests conducted on the water brakes, it would appear that they operated quite successfully. A 1970 report stated that in over 5,000 runs using the water brake and over 4,500 runs using the airgun brake, there were no documented failures. The diaphragm materials on the water brake were changed from one-sixteenth-inch plexiglass to 0.002-inch Pliofilm, and finally to 0.002-inch polyethylene film because early tests showed plexiglass fragments blocked brake orifices and grooves. Goodyear, which had manufactured the film, ceased production of Pliofilm as the results became apparent. [65]

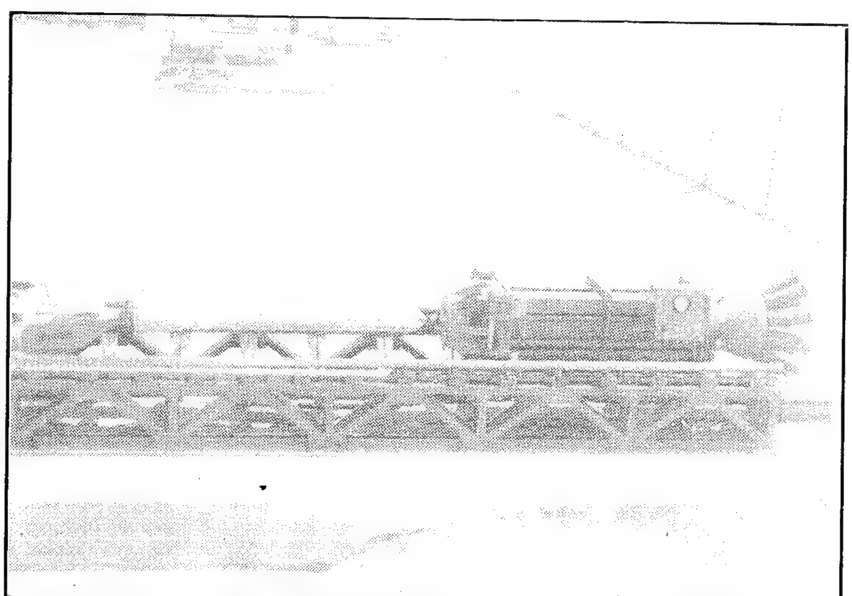


Figure 82. Water brake No. 2 with probe about to enter the brake, ca. 1962 (Space Center archives).

There were different sleds used with the Daisy Decelerator. Sled No. 1 was the sled originally furnished for the Decelerator. It was designed to decelerate a payload of 350 pounds at a force of 200 G. A numerical safety factor was always required. In this case it was 'two,' which gave the ultimate force of 400 G. The sled consisted of a tubular truss built around 4" diameter structural elements. A 6' 6" diameter, 2" thick plywood table was bolted to the top of the truss to form an attachment plane for test items. The table could be removed to permit fastening the payload directly to the truss. One major problem existed with this sled. The seat could be rotated in a 360-degree arc in 15-degree increments, but regardless of the direction of the decelerating force, the test subject was always required to lay on his side.

Slippers provided the bearing between the sled and the rails. The slippers described here are typical of those used on all the sleds. The slippers encircled the cylindrical rails for approximately 270 degrees, with the remaining 90 degrees providing clearance for the rail supports. They were 3.75" wide and 6" long with an inside diameter of 3.125" and an outside diameter of 5.250". The slippers were free to move in pitch and yaw, and vertical and transverse clearances were adjusted by means of shims. A replaceable phosphor bronze bearing insert with a tapered leading edge was installed on the slipper. Prior to each test, the rails were coated with a silicon-base oil. As the slipper passed over the rail, the tapered leading edge contributed to the build-up of an oil film between the bearing and the rail. This effectively reduced the velocity loss due to friction and reduced the slipper wear due to abrasion. Using this method, several hundred tests were accomplished before replacement of the bronze inserts was required. [66]

Sled No. 2 was originally designed to carry a reinforced aircraft-style seat positioned in a vertical plane (Figure 83). After considerable use, during which it was determined that excessive maintenance and structural repair was required, this sled was restricted to animal test programs and was used for equipment checkout. It was later modified to accept noncritical payloads or a human subject on the flat topped portion without undue concern or failure. However, other sleds became available and the nonhuman use continued.

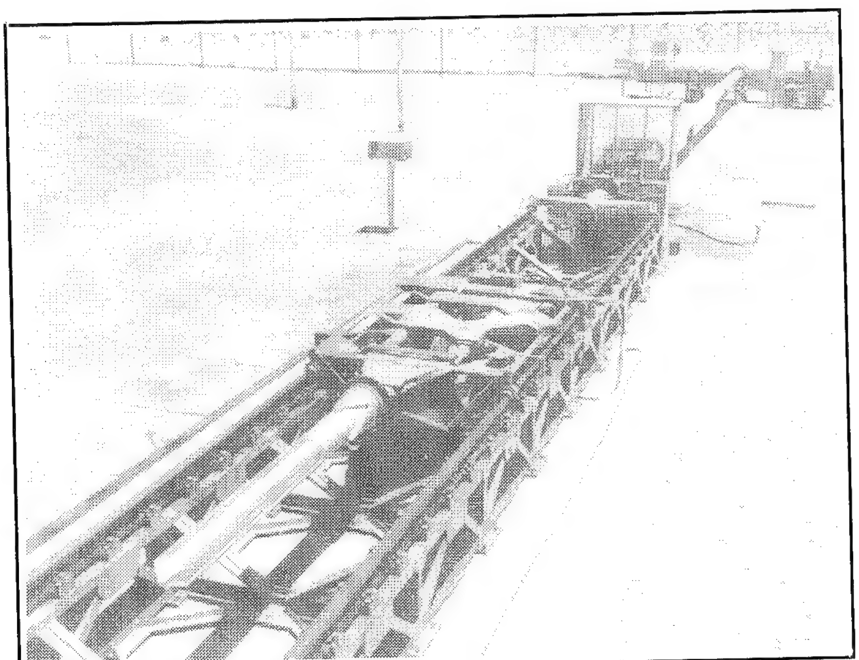


Figure 83. Sled No. 2 on the Daisy Track, ca. 1959 (Space Center archives).

Sleds No. 3 and No. 5 were exact copies of the original No. 2 configuration (Figure 84). A tubular truss framework on each sled carried a steel aircraft upward

ejection seat. To reduce the eccentric loads of the sleds, the seats were placed deep in the structures so the center of gravity of the sleds and payloads lay along the axis of the brake piston. The seats could be rotated around a transverse axis passing through the center of gravity of the combined man and seat. There was a positive lock at 10 degree increments which allowed the seats to be placed in forward or backward facing position. The seats could be removed and replaced with individual contour couches for high level deceleration work or with specially designed fixtures for unusual test requirements. [67]

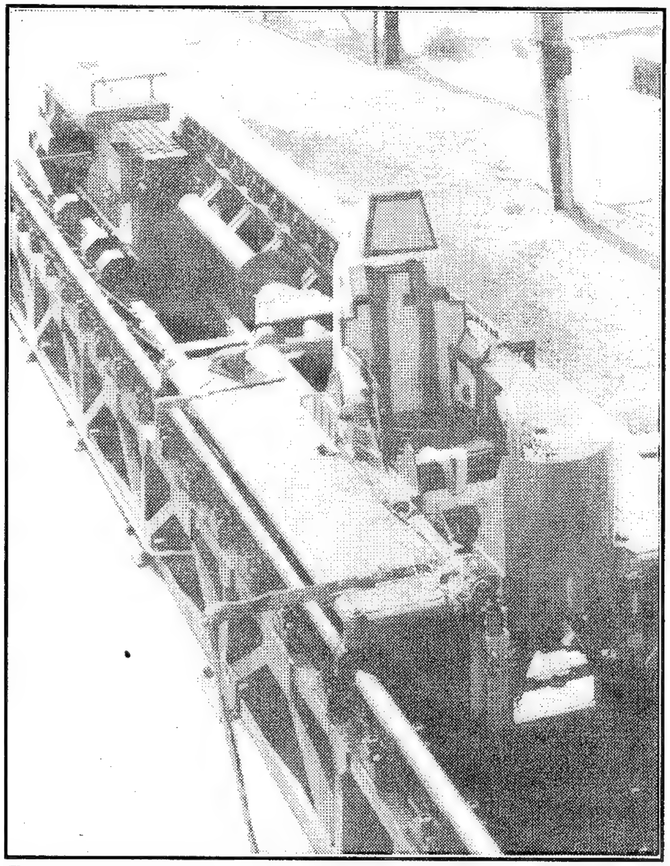


Figure 84. Sled No. 3 on the Daisy Track, ca. 1959 (Space Center archives).

Sled No. 4 was designed to fulfill the requirement for human tolerance tests along any axis of deceleration (Figure 85). It provided for adjustment of the seat along the roll and yaw axis, as well as the pitch axis. The seat was similar to that of the No. 3 sled. There was a gimbal assembly which held the seat and provided two axes of rotation, and a ring which provided rotation of the gimbal and seat assembly about the vertical axis. Sled No. 4 was built to accommodate 250 pounds, including the subject in the seat with personal equipment, and the maximum test deceleration was 100 G with an ultimate safety factor of 'three'. [68]

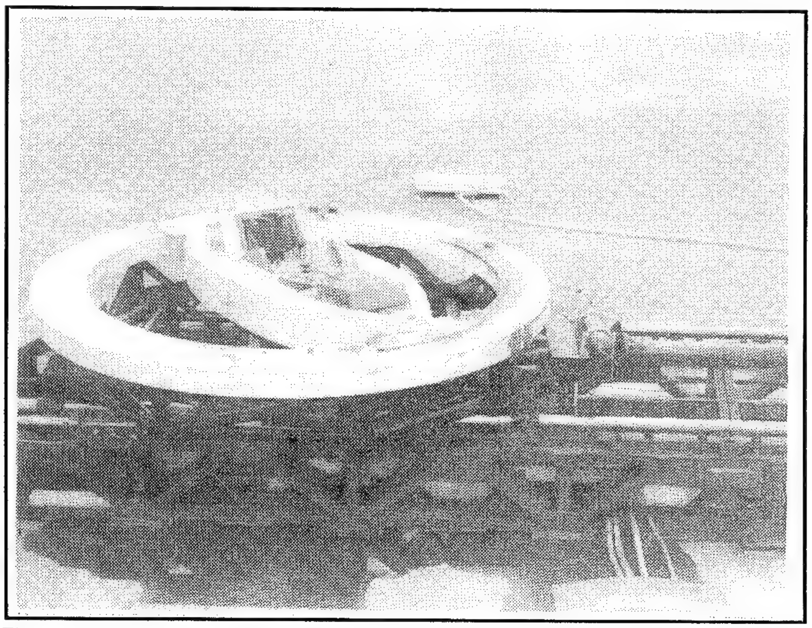


Figure 85. Sled No. 4 with rotational seat assembly on the Daisy Track, ca. 1960 (Space Center archives).

Sled No. 6 was designed to simulate the Apollo space capsule crew couch attachment points in proper orientation to the impact force. This sled tested prototype support and restraint and attenuation systems weighing up to 1,000 pounds at speeds up to 25 G, with the safety factor of 'three'. Because of the space envelope required by the three-man couches and the various impact positions to be tested, the sled was built to be entirely above the track rails. This resulted in a truss assem-

bly about 10 feet in diameter and rising 10 feet above the rails. The center of gravity of the sled, couches, and test subjects was above the line of the deceleration force normally applied by the water brake. To avoid large overturning moments caused by eccentricity between the test item center of gravity and the line of application of the braking force, it was necessary to raise the water brake until the decelerating force was in line with the center of gravity. This was accomplished by the use of a 'water brake spacer,' 52.75 inches high, placed between the water brake and the water brake attachment rails on the track foundation. Operational difficulties of aligning the sled with the raised water brake led to the incorporation of screw adjustments rather than shim adjustments for vertical and lateral positioning of the slippers. [69]

While it was considered 'fun' to run test items and subjects down the track and obtain motion pictures of what they looked like during the test, the photo coverage did not furnish all the data necessary to make a precise determination of what took place during the acceleration and deceleration phases. Other instrumentation had to supplement the motion picture coverage. The Daisy decelerator was designed for maximum versatility and reliability; however, the on-board recorders and transmitters could not meet the test requirements. It was decided that signals would be transmitted from the sled to the data collection center (Building 1200) through an umbilical cable permanently fastened to the sled (Figure 86). This cable traveled with the sled as it moved down the track. To prevent tangles and whipping of the cable, it was anchored at the seventy foot point. Signals were fed into real time displays, recorded on oscillograph paper for quick look data analysis, or recorded on tape for computerized data analysis. The umbilical cable was the electrical link with the sled. It consisted of 27-pair, 54-conductor, No. 22 stranded wires which ran between connectors on a junction panel on the sled and a patch panel in the data collection center. The patch panel provided connections for all the amplifiers, tape recorders, oscillographs, strip chart recorders, velocity measurement system, or any other instrument connections desired (Figure 87). [70]

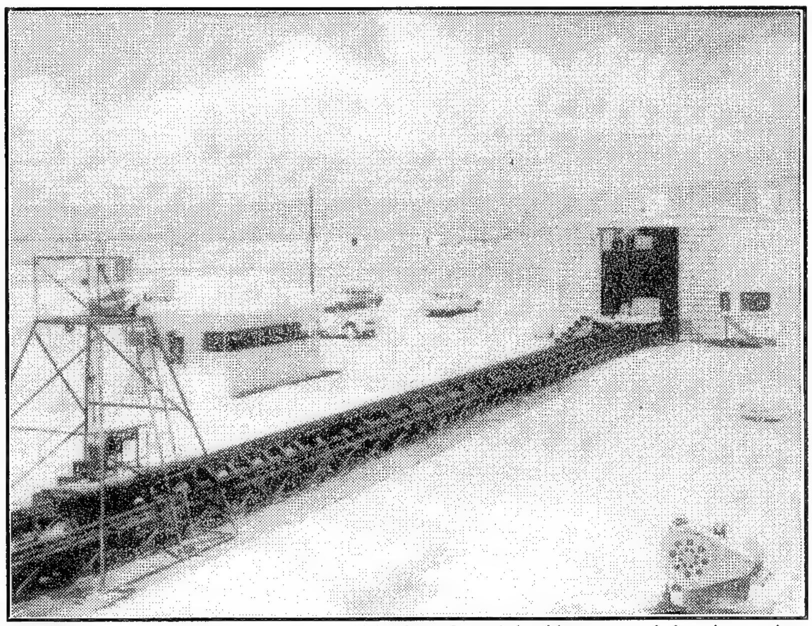


Figure 86. Daisy decelerator from midpoint of track looking toward the airgun in Building 1204, with data collection center (Building 1200) in background, ca. 1966 (Space Center archives).

While 'Vince the Crash Dummy', of television fame, never rode the Daisy Decelerator, a great number of his relatives took a ride and experienced many times the normal force of gravity. In addition to the anthropomorphic dummies which took rides on the sleds, there were bears, hogs, monkeys,

chimpanzees, and even frogs and rainbow trout. [71] Naturally, people wanted the thrill of making the same ride, so there were plenty of volunteers to take this short, exciting trip. Although the first equipment test with the Daisy Decelerator was made on 22 September 1955, and the first chimpanzee test was conducted on 16 November 1955, humans did not start riding the Daisy Track until 17 February 1956. Lieutenant Wilbur C. Blount was the first, and later Dr. Stapp took three rides. [72]

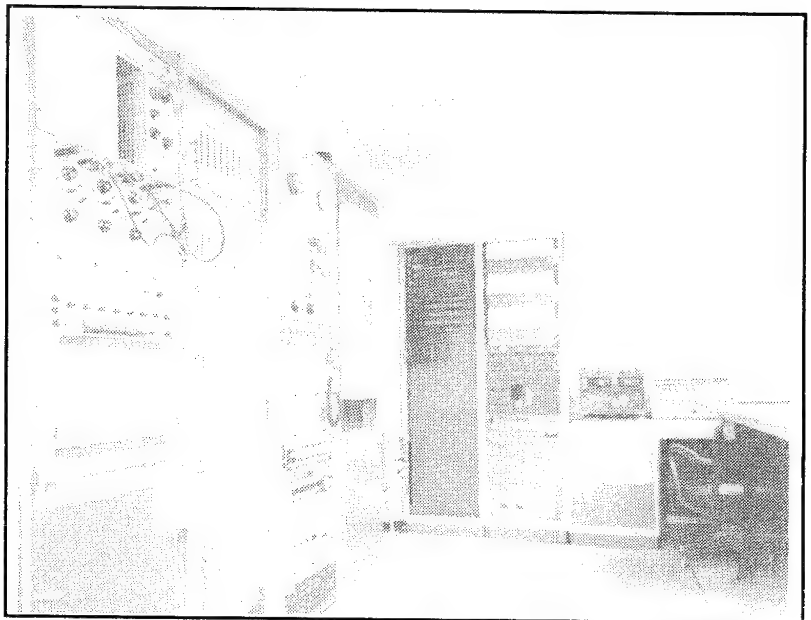


Figure 87. Interior of data collection center (Building 1200), ca. 1962 (Space Center archives).

One experiment involving bears was conducted for NASA in 1962. The ARL acquired twelve American Black, American Cinnamon, and Himalayan Black bears, nine of whom got to ride the sleds on the track. In addition to obtaining data on deceleration, the Apollo couch-restraint system was tested. Three tests were conducted using Sled No. 3, with the remainder using the omnidirectional Sled No. 4. All tests were conducted between 10:30 a.m. and 11:30 a.m. with only a 45-second countdown. On 16 October 1962, the final run with a bear subject was accomplished. On this test, the bear sustained 91.2 G with an onset of 15,700 G per second and a velocity change of 65.8 feet per second. An accelerometer attached to the skull of the bear showed a peak of 168 G. The bear died shortly after the test due to internal injuries. [73]

For a human to take a ride on the Daisy Track, it was not just a simple matter of walking out to the AFL and purchasing a ticket. To be a volunteer, a person had to undergo a Class 3 physical examination that included exams of the eyes, ears, nose, throat, chest X-rays, blood and blood pressure tests, reflex checks, medical history investigation, an electrocardiogram (EKG) and electroencephalogram (EEG), and, probably whatever else the attending physician felt like doing on the side. Complete dental checks were also done as part of the examination.

After passing the examinations, a test date was assigned. Afterwards there was another physical examination before the volunteer got suited up in the test uniform of the day and was wired with EKG and EEG leads so those functions could be continuously monitored during the test run. Next, he climbed into the seat, but did not yet get strapped in. He first had to drink four ounces of barium and have a stomach X-ray. Then there were more blood pressure checks, reflex checks, and even a test of his pulling grip. Finally, he was strapped into the seat, a rubber mouth guard was placed between his teeth, and the countdown progressed. At 'zero', the switch was thrown and he was propelled down the track. The ride seemed to be over before it started, but the work was not done yet. More tests, including

another barium cocktail and a stomach X-ray, were conducted. These were followed by another physical examination. After all that, the test subject had to write a report on his feelings and reactions during the short ride. [74]

Initial test results with the effects of deceleration showed that if the force on the sled was, for example, 40 G, then the force on the body of the subject could be expected to be one and one-half times as great, or 60 G. So, on 16 May 1958, Doctor (Captain) Eli Beeding was strapped into Daisy Track Sled No. 2 and, facing backward, was fired down the track at a force of 40 G. Test results showed that somewhere along the projected curve of force on the sled versus force on the body, the curve changed from a linear rise to an exponential rise. Doctor Beeding sustained a force of 83 Gs on his body during that famous ride. After the test run, Doctor Beeding made a comment about his fellow passengers, two white rats, saying "they didn't even go into shock." Dr. Beeding, on the other hand, went into shock, but recovered in less than ten minutes. His was the 335th run on the Daisy Track. [75]

Many different tests were conducted using the Daisy Track. Integrated harnesses for B-52 and F-104 aircraft and force attenuating seat cushions were tested. The track was used to check out recording equipment for the HSTT prior to its use on rocket sleds. [76] The Daisy Track was even used during air bag tests. [77]

Like all good things, the Daisy Decelerator finally came to an end in the early 1980's. There were newer and better ways to run the tests and get the desired data. Destined for the salvage yard, the Daisy Track was rescued from oblivion on 13 January 1987, and is now awaiting restoration and display at the ISHF in Alamogordo, New Mexico.

Project Excelsior

In March 1912, Captain Albert Berry of the United States Army made the first successful parachute jump from an aircraft. The jump occurred at Jefferson Barracks, Missouri, where Berry was stationed. The parachute was contained in a cylinder underneath the open cockpit airplane. Berry climbed out of the cockpit, slipped into the parachute harness, and jumped. [78]

Exiting a crippled aircraft has changed greatly since that first jump by Berry, but the parachute itself has changed little since those times. The basic elements of a parachute are still (1) the canopy, (2) the harness, (3) the shroud lines, (4) the container with locking and releasing mechanism which holds the canopy and shroud lines, and (5) the pilot parachute. [79]

As aircraft became faster and flew higher, the problems associated with bailout compounded rapidly. When bailing out of a high performance jet aircraft at high altitude, the pilot was faced with having to free fall to a lower altitude because of the extreme cold and insufficient oxygen at the bail out point. It was also discovered that the tendency of a falling body to get into an accelerating flat spin could be fatal. This was not simply a rotation of the body which could be understood and mentally compensated for; the rotation could quickly reach violent and lethal proportions. [80] People who sky

dive and perform aerial ballet while falling are not faced with this problem. However, their jump from an aircraft is done at a much lower speed and at a lower altitude where the air is more dense. Since half the atmosphere is below 18,000 feet, flight at high altitude occurs where the air is really thin.

Tests conducted by the Aeronautical Research Laboratory at Wright Air Development Center demonstrated that a falling body could reach the rate of 465 revolutions per minute about the vertical axis of the body while it was in the prone position. If a pilot bailed out at high altitude, he had little choice other than to fall. Therefore, equipment was needed to stabilize the jumper during the fall. In addition, this equipment needed to be tested to ensure that practicality agreed with theory.

Anthropomorphic dummies were drafted as test subjects. The dummies weighed 200 pounds and were 72 inches (six feet) tall. Using a C-97 at HAFB, researchers made 35 drops of dummies from altitudes ranging from 25,000 feet to 35,000 feet. These tests, conducted between 1957 and 1958, were accomplished at indicated air speeds up to 202 mph. During the tests, the dummies reached spin rates up to 200 revolutions per minute. In addition to drops from an aircraft, there were 21 drops from balloons at altitudes ranging from 91,000 feet to 102,000 feet.

Early psychological evaluations showed that pilots who bailed out had a tendency to try to remain with the last link of their aircraft: the seat. Some even rode the seat down instead of separating and using their parachute. Consideration was given to attaching a drogue parachute and stabilization fins to the seat, but this did not solve the problem. Man-seat separation devices were developed which 'threw' the pilot out of the ejection seat. Therefore, the next step was to stabilize the pilot with a drogue parachute. [81]

Parachute expert Francis F. Beaupre developed a stabilization parachute which, in theory, would work. The theory was put to a test on 27 October 1957 with a jump from a C-130 at about 30,000 feet. Beaupre's stabilization parachute worked. After bailout, the pilot would pull the 'orange apple,' which started the parachute deployment sequence. The first to deploy, after a few seconds delay, was an 18 inch pilot parachute. This, in turn, pulled out a 6 foot stabilization parachute, followed by three-quarters of the main parachute. When the person passed through a predetermined altitude, which in the early 1960s was determined to be 14,000 feet, the aneroid barometer would start the release sequence allowing the 28 foot diameter main parachute to fully deploy. This test showed the Beaupre stabilization parachute worked at altitudes where jet aircraft were normally flying. It then became necessary to see if the system would work at higher altitudes where the X-15 and other research aircraft and space capsules would fly.

Accordingly, the ARL at HAFB began a series of parachute test using balloons, under the name 'Excelsior.' On 16 November 1959, Captain Joseph W. Kittinger Jr. was launched in an open gondola balloon from a point north of Truth or Consequences, New Mexico. Attached to Kittinger were electrodes for monitoring his heart beat and his respiration. A radio for communications and in-flight recording of data was contained in the seat instrument pack. He wore a Beaupre backpack parachute and an automatic chestpack reserve parachute. Kittinger was seated on a styrofoam seat which had holes

containing water bottles cut in the foam. The styrofoam furnished insulation and the water provided heat. As water freezes it produces heat and one pint of water, for example, will produce 60 watts of heat.

External support for this mission, called Excelsior I, was provided by a B-57 aircraft that would take photographs during the ascent. A C-123 was airborne for support at medium altitudes, while a helicopter gave low altitude support. Numerous cameras were used for this mission, placed in the aircraft, the balloon, and on Captain Kittinger.

Upon reaching the predetermined jump altitude, Kittinger found he had difficulty getting up from his seat. When the water bottles froze, they expanded and were holding the instrumentation kit to the seat. In the process of trying to stand up, which took 11 seconds, he accidently activated the timer for the stabilization parachute. This early activation of the timer caused the pilot parachute to deploy before his falling body had gained enough speed to properly deploy the system. It was supposed to deploy 16 seconds after Kittinger left the gondola, but actually deployed at two and one-half seconds after he jumped. In fact, the main parachute wrapped around Kittinger's neck and he could not get it unwrapped. The aneroid opened the reserve parachute at an elevation of 11,000 feet and the canopy was fully deployed at 10,000 feet, which was only 6,000 feet above the ground. Beaupre's modifications to the reserve parachute saved Kittinger's life. [82]

Changes were made after data from the first test was analyzed. The water bottles were relocated and there were procedural changes in the activation of the timer. On 11 December 1959, at 6:30 a.m., Kittinger lifted off on the Excelsior II mission. Everything worked perfectly during this mission and he spent twelve minutes, thirty-two seconds in the descent from altitude. [83]

One more test remained, a parachute jump from a still higher altitude. At 5:29 a.m. on 16 August 1960 Kittinger lifted off from an old abandoned airstrip just north of Tularosa, New Mexico, and east of Highway 70 (Figure 88). During the ascent of Excelsior III, the pressure in Kittinger's right glove failed due to a crack in the oxygen line. This would have been enough to abort the mission, but Kittinger did not initially report the problem because he did not want to terminate the test. He reported it just prior to stepping out of the gondola. [84]

Normally, at a 60,000 feet, the swelling of the balloon envelope had a drag strong enough to damage the plastic. To prevent this damage, the ascent rate had to be reduced. [85] Kittinger was able to reduce the climb rate and the ascent continued to an altitude of 102,800 feet, where he had 99.2 percent of the earth's atmosphere beneath him. Once again, the Beaupre multistage parachute functioned perfectly. During this mission, Kittinger experienced four minutes and thirty-seven seconds of free-fall during the thirteen minute, five second descent. [86]

The achievements by Kittinger during Project Excelsior were (1) proof by survival that the Beaupre multistage parachute could provide stabilized free-fall descent from altitudes greater than 20 miles, (2) proof that the MC-3 partial pressure suit and other items functioned under actual emergency open-air conditions, since previously they had been tested only in altitude chambers, and (3) demonstration that

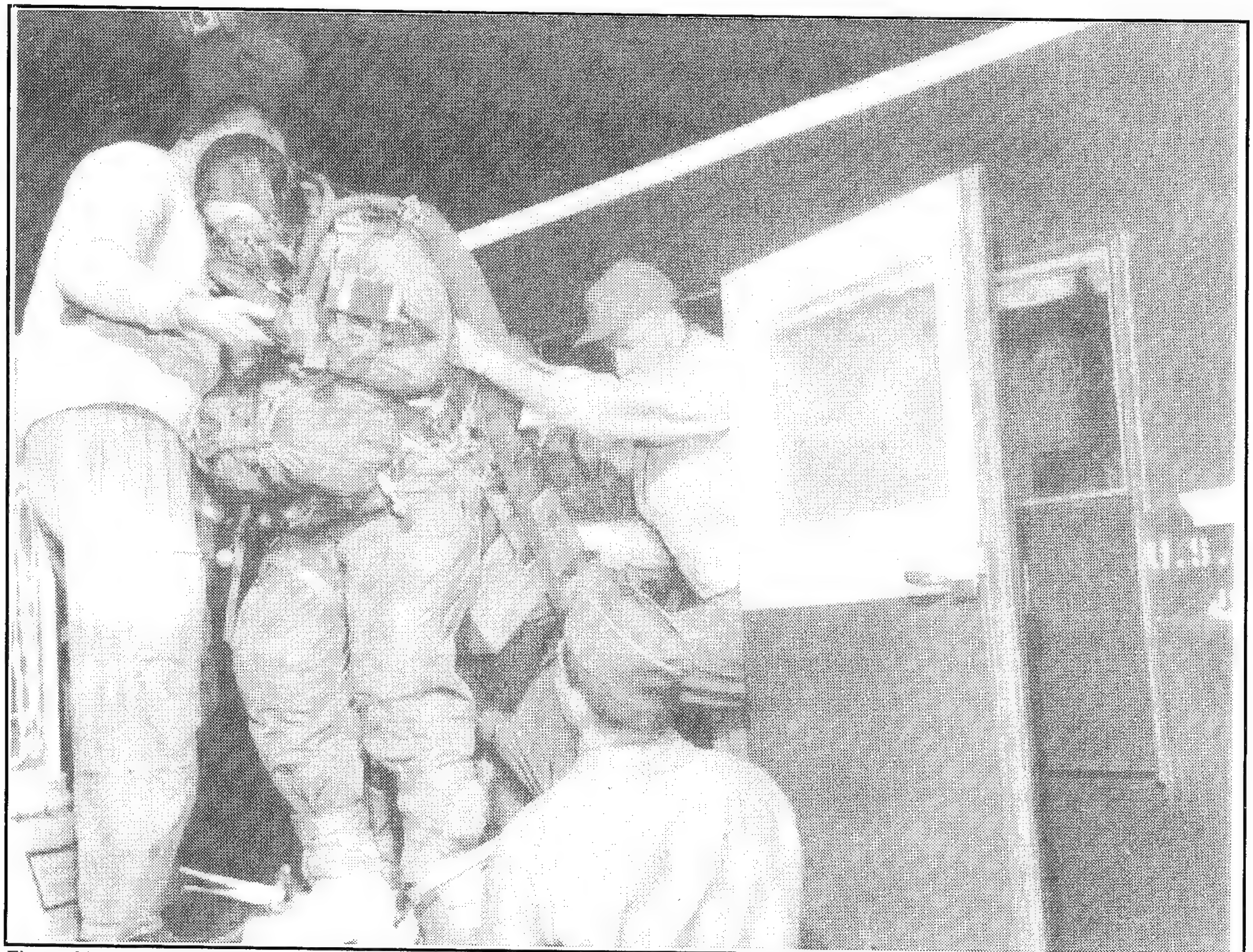


Figure 88. Captain Kittinger, Jr. exiting his dressing van prior to the Excelsior III flight from the Tularosa airport, 16 August 1960. He needs the assistance of two men because of the weight of his suit and flight gear (Space Center archives).

a man exposed to the stresses of space emergency conditions could, with minimum protection, endure and perform for more than an hour and override equipment failures. [87]

Project Manhigh

Project Manhigh was a United States Air Force balloon flight program designed to investigate the human factors of space flight by taking men into the stratosphere. Since space is considered a hostile environment, the Air Force needed to know how humans could survive there and sought to discover more of the design principles for space capsules and how to study men and their reactions when in space. The collection of such data would permit intelligent planning of future space flight experiments.

Background History

The use of balloons to enable men to reach higher altitudes was nothing new to the Air Force. When the Air Force was known as the Army Air Corps, two officers made a world-famous balloon flight into the stratosphere. On 11 November 1935, Captain (later Major General) Orvil A. Anderson

and Captain (later Lieutenant Colonel) Albert W. Stevens rode Explorer II to an altitude of 72,395 feet. [88]

Prior to the advent of the Manhigh Project, animals had been sent aloft in balloons over a four year period to determine the effects of altitude. These flights were designed to develop a sealed cabin for extended flights of up to 36 hours at altitudes to 126,00 feet. This was above 99 percent of the earth's atmosphere, and the goal of these flights was to study the biological effects of cosmic radiation. These animal subject flights were made from Fleming Field, South St. Paul, and International Falls, Minnesota, and Sault Sainte Marie, Michigan. The flights were successful and led to Project Manhigh.

In the spring of 1956, Headquarters, Air Research and Development Command, approved Project Manhigh. Dr. John P. Stapp, who was then chief of the Aeromedical Field Laboratory, Air Force Missile Development Center, had approved the project at the local level and forwarded it through channels to obtain the necessary headquarters approval. Dr. David G. Simons of the Aeromedical Field Laboratory, HAFB, was appointed the Air Force Project Officer. [89]

During this period, the 6571st AFL was an integral part of the AFMDC, and management responsibility rested with HAFB personnel. Contracts for the construction of the balloon and capsule and for launch support were let to Winzen Research Inc., Minneapolis, Minnesota. Planning was jointly conducted by HAFB and Winzen personnel. Because there was no balloon pilot training capability in the United States Air Force, training was also obtained by contract with Winzen. The Air Force, and in particular HAFB and Winzen Research Inc., were the major players in these pioneer flights to the edges of space.

The Air Force has always considered safety to be paramount, and it was given major attention in Project Manhigh. Before men were allowed to ascend in the capsule, there were six unmanned flights to test all portions of the system. These tests were to obtain data on launching methods, balloon performance, capsule environmental maintenance, capsule parachute recovery, and instrumentation and photographic techniques. During these unmanned tests, data was obtained showing the capsule parachute opening sequence at 112,000 feet, parachute stability, capsule opening and separation during simulated emergency descent, as well as a great deal of other information.

The pilot of the Manhigh balloon was not neglected. His preparation included a parachute jump, a 24-hour claustrophobia test in the capsule, and numerous ground tests using the capsule climate control system, including a test in the high-altitude, low-temperature test chamber at Wright Air Development Center (now Wright-Patterson AFB). In addition, the pilot was given numerous blood tests for the study of cosmic radiation effects and subjected to a battery of physiological tests. Pilots were also trained as balloon operators and were required to make a solo balloon flight and qualify for their balloon pilot license. [90]

The capsule used for the Manhigh I flight was designed and manufactured by Winzen Research Inc.. It was an aluminum-alloy, hermetically-sealed unit 8 feet high and 3 feet in diameter, with hemispherically-shaped ends (Figure 89). The capsule was supported in an upright position by a tubular aluminum structure with various expendable equipment attached. This structure was especially designed to serve as

a shock-absorbing system during landing operations. The capsule shell was constructed of three separate sections hermetically sealed together by two circumferential clamps. The primary structural member of the system was the aluminum alloy casting which formed the center section of the capsule shell. This turret casting, with six portholes, was the load-carrying member for almost all the internal structure and equipment. The capsule was attached to an open, 40.4 foot extended skirt parachute with six suspension fittings positioned circumferentially around the turret casing. The parachute was, in turn, attached to the balloon by a stabilizing suspension system to retard any capsule oscillations during the flight.

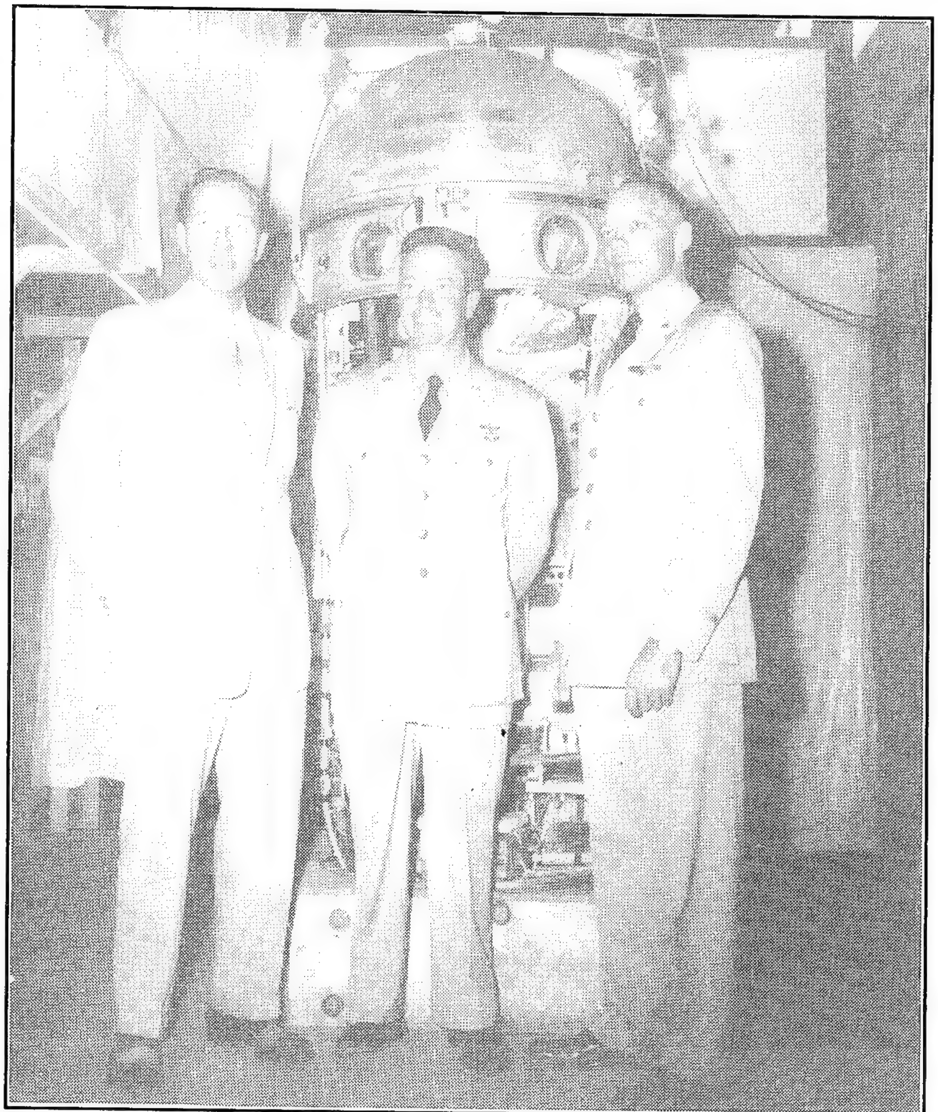


Figure 89. (L- R) Otto Winzen, Joe Kittinger, and Dave Simons beside Manhigh Capsule, ca. 1957 (Space Center archives).

A pressure equivalent to that of 26,000 feet was selected as the control pressure in the capsule. The oxygen for the pilot's breathing and for cabin pressurization was provided by a 5-liter liquid oxygen converter and a 205-cubic-inch, high-pressure bottle. An emergency 90-cubic-inch bailout supply was installed in the personal parachute harness worn by the pilot. [91]

The sealed atmosphere in the capsule was chemically treated to remove carbon dioxide and moisture, and an external water evaporation cooling system was used to maintain the capsule temperature at a comfortable level. The removal of carbon dioxide and water vapor was accomplished by a chemical air-regeneration unit located external to the capsule. The chemicals used in the regeneration system were (1) anhydrous lithium chloride, which served to remove moisture, (2) anhydrous lithium hydroxide, which served to remove the carbon dioxide, and (3) anhydrous magnesium perchlorate, which removed moisture formed by the reaction between the carbon dioxide and anhydrous lithium hydroxide.

The chemical air-regenerative system consisted of 30 cylindrical nylon bags, 18 inches long and 2 inches in diameter, containing the absorptive chemicals and placed in a 12 inch diameter vertical cylinder. The axis of the bags were parallel to the axis of the cylinder. The capsule atmosphere was drawn from the bottom of the capsule at the rate of approximately 25 cubic feet per minute, passed by the chemicals, and then returned to the upper part of the capsule. The total weight of the chemicals and the bags was 13,054 grams. Postflight analysis of this system showed that the average rate of collection of carbon dioxide was 66.5 grams per hour (0.1465 pounds per hour). [92]

Electrical and communications equipment was primarily installed inside the capsule. The main exception was the lead acid battery power supply. The batteries, mounted on the lower undercarriage ring and equipped with individual parachutes, were used as ballast when expended. In addition to the battery ballast, fine control was made possible by dropping steel shot through a metering valve mounted below the ballast container. A total of 246 pounds of ballast was carried on this flight. [93]

The communications equipment for Manhigh I included a Very High Frequency (VHF) transceiver with an integral Visual Omni Receiver (VOR) receiver and a High Frequency (HF) receiver for voice communications. In addition, there was a telemetering transmitter for Continuous Wave (CW) transmission in the event of failure of the voice communications system. [94] Sequence cameras provided continuous recording of the flight progress, including photographs of the instrument panel and of the earth during the flight.

The balloon used for the flight was also manufactured by Winzen Research Inc.. It was fabricated from 2 mils thick polyethylene film . The inflated volume of this aerostat was two million cubic feet. At the apex of the balloon was an electrically-driven, 14 inch diameter, fail-safe gas valve controlled by the pilot from the capsule. The valve was used to release helium gas from the balloon in order to decrease the rate of ascent, and initiate or increase the rate of descent. [95]

At 12:30 a.m., Central Daylight Time (CDT) on 2 June 1957, the pilot of Manhigh I, Captain Joseph W. Kittinger Jr., entered the capsule and began his final equipment check. The capsule was then sealed and checked to ensure it was pressure tight. Technicians flooded the capsule's atmosphere with helium, eliminating any nitrogen in the sealed environment. Eliminating the nitrogen reduced the possibility of Kittinger getting the bends in the event of a rapid decompression of the capsule at high altitude.

Initial preparations for the flight were completed at 3:30 a.m. and the capsule was transferred by truck to Fleming Field. The truck arrived at 4:30 a.m. and final flight preparations commenced immediately. At 6:20 a.m. the wind was peaking at about two knots and meteorological conditions were considered ideal for the flight. At 6:23 a.m. the balloon was released from the restraints and the flight portion of the Manhigh I mission was underway. [96] At the time of launching, tracking and photographic aircraft were airborne and included an Air Force C-47, two Air Force helicopters, and a Navion chartered by Winzen Research. [97]

A communications problem developed approximately 20 minutes into the flight and Kittinger ad-

vised controllers he was going to check other channels on the VHF transceiver. As he turned the channel selector knob on the transceiver, a mechanical failure of the selector resulted in the inability to determine the frequency the equipment was tuned to. Kittinger was unable to transmit voice communications throughout the remainder of the flight. His only transmissions from that time on were accomplished using the physiological and altitude telemetering HF transmitter as a CW code transmitter. The HF voice receiver was still operating properly, and he was able to receive instructions from the ground. Later, during the ascent, receiving ground instructions became difficult because the proximity of a commercial broadcasting station transmitting on a wave length near that of Manhigh I's HF receiver caused bleed-over.

Shortly after launch, it became apparent to Kittinger that the capsule's internal pressure was responding very slowly to the change in altitude. Since the pressure response rate had never been experienced under actual flight conditions, an immediate evaluation could not be made determining whether this was a problem. At 8:07 a.m., Kittinger reported his liquid oxygen supply was down to 2 liters. A conference was called in the Command Post and Dr. Simons, Dr. Stapp, and O. C. Winzen discussed the situation. However, more information was needed from Kittinger before evaluation of the problem was possible. During this period, the balloon was floating at its ceiling altitude of 95,200 feet. It was then determined that, due to the rapidity with which the oxygen supply was being depleted, the problem lay with the cabin pressure controller. Therefore, a decision was made to start a descent at 8:54 a.m.. [98]

Communication with the balloon became difficult and control was transferred to the C-47 aircraft. At approximately 10 a.m., Kittinger was advised to switch his oxygen supply to the pressure suit to conserve the remaining oxygen. This procedure definitely established that the cabin pressure controller was responsible for the excessive use of oxygen. By closing the vent valve for this unit, it was possible to resume the normal capsule atmosphere breathing procedure by manually replenishing the oxygen through the constant flow valve as required.

By this time, cloud cover had obscured the balloon from view of the C-47, so the command function was transferred back to the Command Post at the Winzen plant. The C-47 landed and remained on the ground until 11:30 a.m., when Kittinger reported the balloon had descended to 53,000 feet. Shortly after 12:30 p.m., the balloon was sighted below the clouds. Since the descent rate was too high, it was retarded by dropping part of the external batteries on their individual parachutes. Surface winds were quite high and the terrain was heavily wooded, but in spite of these obstacles, Kittinger was able to execute his landing with commendable control. At 12:55 p.m., the capsule settled into a small clearing on the bank of Indian Creek, just north of Weaver, Minnesota. At the moment of contact, the balloon was released and the capsule toppled into the shallow water of the creek. Two helicopters landed in the clearing and crewmembers helped Kittinger out of the capsule, concluding the flight which carried Captain Joseph Kittinger to the highest sustained altitude achieved by man until that time.

Postflight examination revealed the pressure supply line and overboard vent line to the cabin pressure regulator had been crossed during installation. That resulted in the oxygen supply being dumped

outside rather than inside the capsule. In spite of the numerous tests performed on the ground, the operating characteristics of the regulator were such that the error was not discovered. The flight, which had a planned duration of 10 to 12 hours, had to be shortened considerably because of the oxygen line problem. [99]

Manhigh II used the same capsule configuration as that of Manhigh I, with some changes brought about from data obtained from the first flight. The pilot of Manhigh I had complained about the relatively low level of illumination inside the capsule at altitude. The Manhigh II capsule, therefore, represented the first attempt at astrochromatics, the interior decoration of a space ship. The upper hemisphere of Manhigh II was painted white on the inside over-layer of insulation material. The various emergency controls were color-coded, as were the portholes and instrument panels. Pastel colors of restful hues were chosen to generate a feeling of a pleasant, cheerful surrounding. Tests showed the illumination resulting from the white hemisphere in Manhigh II was roughly three times as high as that resulting from the light blue surface used in the Manhigh I upper hemisphere. [100]

The balloon vehicle used for the Manhigh II flight represented the largest plastic balloon in production at that time. It had a volume in excess of three million cubic feet and at ceiling altitude reached a diameter of 200.2 feet. It was constructed of 1.5 mil gage (0.0015 inch) polyethylene. [101] The pilot's seat was the first operational application of an integrated body support system for the achievement and maintenance of optimum comfort and accommodation over an extended period of time. In short, it proved that the man and his personal equipment must be integrated into the seating system. [102]

In preparation for the high altitude flight, photographic plates were taped to the arms and the chest of the pilot. These plates were to record the impact of cosmic ray particles in an effort to determine if they would have adverse effects on the pilot. Instrumentation also recorded his pulse and respiration rates. [103]

It was 10 p.m. CDT on 18 August 1957 when the pilot of Manhigh II, Dr. David G. Simons, settled into the nylon net seat of the capsule for the start of his record breaking flight. Dr. Simons almost had a 'copilot' on his flight; at one point it had been decided to send up a monkey in the capsule, not so much to keep Dr. Simons company, but to provide another cosmic radiation test subject. The monkey had already been selected and shipped to Wright Air Development Center for a final chamber test of the capsule. However, at this point, Dr. Stapp grounded the monkey and Dr. Simons went up solo. After settling down, Dr. Simons found a neatly typed note stuck to one wall of the capsule: "Have all the fun you want, but don't jump up and down." It was signed by Otto C. Winzen, who had built the balloon and the capsule. Shortly after that, Dr. John P. Stapp reached in and shook hands with Dr. Simons. His parting message was: "Major, you are about to reach the high point of your career." [104]

After completion of the checklist and ensuring all items were present and accounted for, the capsule was lifted into the air and lowered into its shell at 11:45 p.m. The usual cap of dry ice was placed on top of the capsule for cooling purposes, and the process of elimination of nitrogen from the atmosphere was begun. Then, at 12:37 a.m. on 19 August 1957, the capsule was loaded on the back of a

truck for the 150 mile trip from the Winzen plant to a deep open pit iron mine at Crosby, Minnesota. Launching the balloon from this pit would give an extra 425 feet of calm air necessary for a balloon the size of Manhigh II. [105,106]

At 5 a.m. the truck, capsule, and pilot arrived at the pit. The pilot reported that he had managed to obtain several 10 to 15-minute naps during the nearly five-hour trip to the pit. The combination of the dry ice and the cool night air had created an uncomfortably cold environment in the capsule and, since Dr. Simons was soaking wet under his pressure suit, it was even more uncomfortable. [107]

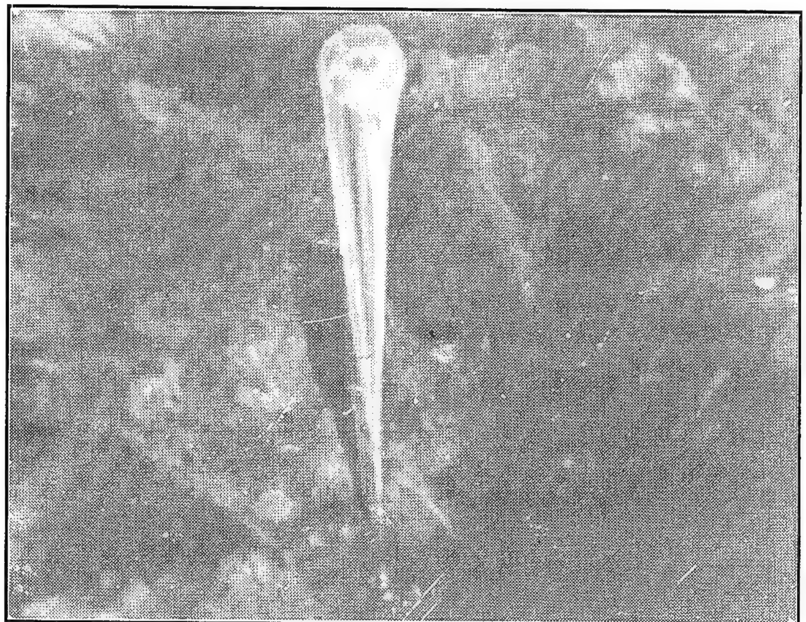


Figure 90 . Lift-off of Manhigh II from an open pit mine in Crosby, Minnesota, 19 August 1957 (Space Center archives).

During the launch preparations, an unusual mishap occurred. A reefing sleeve, which tightly sheathed the uninflated part of the balloon to protect loose folds from being caught by the wind, malfunctioned. When the balloon was inflated and was ready for launch, the upper band of the reefing sleeve tore loose and was binding the balloon 30 feet above its bottom. This problem was resolved by Vera Winzen, who climbed a ladder supported solely by ropes and cut the band with her scissors. [108] A slight wind had come up, and it was necessary for the launch crew to walk the capsule and balloon to one side of the pit to ensure it would clear the sides of the pit after release. Moving the balloon worked, and a successful launch was accomplished at 9:22 a.m. (Figure 90).[109]

The balloon ascended at a rate of 1,200 feet per minute and, after valving per instructions from the ground, an ascent rate of 1,000 feet per minute was attained. Dr. Simons took pictures and readings and, as the balloon ascended, the chilled capsule became colder. The planned schedule of events was interrupted due to cold fingers. Photographs were taken, but unfortunately the tape recorder was inoperative from 8:15 a.m. until 10:15 a.m., so valuable comments by Simons were lost. [110]

Two hours and 18 minutes after launch, the balloon reached its 100,000 foot ceiling. Simons made numerous observations, took photographs, and recorded data (Figure 91). One of the data items recorded was the capsule temperature. The side of the capsule facing the sun was warm, while the side away from the sun was cold. Portholes on the shadow side of the capsule exhibited moisture condensation, and those on the sunlit side remained clear. In addition, ice that had accumulated on the inside surface of the dome was melting, allowing the water to drip on Simons and on much of the instrumentation and throwing an additional load on the air regeneration system desiccants. [111]


Figure 91. Dr. David G. Simons during Manhigh II flight, Aug. 19, 1957 (Space Center archives).

At 4:30 p.m., the balloon started to lose altitude because of the decrease in the warming effects from the sun. In the meantime, internal capsule temperature had risen. A radio conference between the ground Command Post and Dr. Simons resulted in the decision to remain airborne all night. At 4:50 p.m. the sun set and the pilot viewed the spectacular sight of thunderheads illuminated from within by lightning. The balloon started descending more rapidly than anticipated, so ballast was released. Simons knew he had to remain above the storm clouds or the balloon would be torn to pieces. [112]

The temperature in the capsule dropped to 55 degrees F by 2:30 a.m., and Simons felt cold and clammy. He spent about 30 minutes in an intense, patient effort to get into his thermal suit, which he did slowly and carefully to avoid sending thermal shocks to the brittle balloon above him. Then, after making observations at about 3:10 a.m., Simons fell asleep. When he awoke, the capsule was rotating, an indication that it was changing altitude. The altimeter revealed that the descent rate was too great and the balloon was approaching thunderheads. More batteries were dropped and the balloon began to rise. [113]

There was a faint glow of dawn on the eastern horizon well before the sun became visible. Finally, at 6:50 a.m., the sun broke across the horizon, providing the sight of a green flash. The sun caused the gas in the balloon to heat and expand which raised the balloon to a higher altitude. Ground control then ordered Dr. Simons to eat. He had been so engrossed in his work that he had neglected to eat properly. After eating and obtaining the required data, Simons noted the capsule internal temperature had gone from near freezing to 55 degrees F. He then removed his thermal clothing. [114]

The pilot and the ground crew became aware that it was taking an excessively long time to obtain readings, and these were prone to error. A check of the level of carbon dioxide revealed it was high, at four percent, so Dr. Simons went on pressure suit oxygen and resolved the problem.

Descent was initiated at 11:04 a.m. by valving off helium. However, the desired descent rate was not obtained, so an increase in descent rate was initiated. Care had to be exercised, because when passing through the tropopause around 40,000 feet, the descent rate increases approximately 50 percent. During the descent, Simons noted an uncomfortable feeling just below the shoulder on his right arm. He later discovered that the telescope mirror was adjusted at the precise angle to catch the sun, and

the image was focused on his right arm. Fortunately, the pressure suit avoided burning. [115]

After stowing all equipment and preparing for landing, Simons prepared to release the balloon after the capsule touched down. The force of landing threw his arm into his lap, and since the jettison switch was operated with an upward motion, the capsule was dragged a few hundred feet before balloon separation. Simons released the top of the capsule and crawled out at 5:32 p.m. [116] During this flight, Simons' balloon achieved a world's altitude free balloon record of 101,516 feet (30,942 meters). For this achievement, he was awarded a certificate from the Federation Aeronautique Internationale. [117]

Manhigh III's flight system was very similar in size and shape to that of Manhigh I and II, with many refinements and additional equipment incorporated. One of the changes included enlarging the capsule to 9 feet in length. The diameter remained at 3 feet. [118] One unit that reflected considerable difference was the air regenerator. The previous flights utilized this unit outboard, ducting the air from the capsule out and back. The Manhigh III unit was inboard, with a blower picking up the capsule atmosphere directly. The chemicals previously used were discarded in favor of potassium hydroxide (KOH), because it offered greater activity in absorbing carbon dioxide and had the ability to absorb water. The new air regenerator system used 16 pounds of KOH in stick form inserted into one-half inch diameter steel spring retainers. Because KOH is so caustic, valves were installed in the outlet and inlet which could be manually operated by the pilot to seal off the unit during landing. The unit was also designed so no liquid would reach the ports if the regenerator were laying on any side, a likely condition if the capsule landed and fell over. [119]

Manhigh III was initially scheduled for launch in Minnesota in August, but the project was delayed until September, a time when the winds were expected to be too adverse for balloon flights. The same situation applied to a launch from Rapid City, South Dakota. Fortunately, the weather in southern New Mexico was satisfactory. Changing the launch to HAFB would result in the loss of cosmic radiation data and required that the recovery would be the responsibility of the AFMDC Balloon Branch. This group was well trained and acquainted with balloon tracking and recovery techniques. However, they had never integrated their efforts with a contractor group, causing them some concern. As it turned out, this concern was unwarranted. [120]

Holloman Air Force Base Programs

After the decision to move to HAFB was reached, an Air Force C-47 left Minnesota on 3 October 1958 with all necessary equipment, including the only two balloons manufactured to manned flight specifications. On 5 October, a meeting was held to brief all personnel on the new operations plan. The wind forecast for the next day, Monday, did not look favorable, but the winds for Tuesday morning looked promising. A command decision was made on the afternoon of 6 October to prepare for flight unless the wind situation deteriorated. [121]

The pilot was given his final physical check and was then sealed in the capsule. The capsule checked out without difficulty and was brought to the launch site on schedule. The launch point selected was as

the HAFB runway immediately north of the Balloon Branch building in the West Area (see Figure 4). At 6:25 a.m., the rays of the rising sun illuminated personnel who were refilling the dry ice cap on the capsule, and balloon inflation was ready to begin. Barely 10 minutes before inflation could have been completed and the flight launched, a gust of wind caught the balloon and destroyed it. The launch was rescheduled for the following morning using the remaining balloon. [122]

On 8 October, the mission proceeded normally up to the point where a person on the ground asked for a reading of item seven from the checklist. As the pilot, Lieutenant Clifton M. McClure turned to comply with this request, the chest pack parachute, whether through improper packing or the accidental pulling of the ripcord, popped open and the parachute dropped into his lap. The parachute, included for pilot escape if the emergency capsule parachute malfunctioned, was one of a kind. It was specially rigged for use in this capsule and there was no replacement at the AFMDC. Although he was not trained as a parachute packer, McClure had, several months prior, carefully observed the packing procedure and satisfied himself that he knew how each step was accomplished and why. If the popped parachute was reported, the mission might get delayed beyond the good weather. McClure exerted superhuman effort to not only repack the parachute once, but twice. The first time he realized he had done something wrong, so he took it apart and repacked it a second time. At last the parachute task was complete, but it was only 20 minutes prior to launch. For the first time in hours, McClure could relax. [123]

Apparently, McClure was reporting a cooler, more comfortable capsule temperature during the preflight than he had reported the day prior. Therefore, contractor engineers decided not to repack the capsule dome with dry ice, but to send the balloon aloft without additional cooling. On previous Manhigh missions, the dome had been repacked with dry ice within an hour of launch.

At 6:51 a.m. on 8 October 1958 the Manhigh III flight cleared the ground and the mission was underway. The initial ascent rate required McClure to valve off excess free lift during the first half-hour. Instrumentation and voice communications seemed to be working well. Telemetry exhibited a little interference, but all channels appeared to be functioning properly. However, the panel temperatures as read by McClure were inordinately high at 118 degrees F. It was soon discovered that because of an error in placement of the sensing element, this reading was meaningless. [124]

Ceiling altitude of almost 100,000 feet was reached at about 10 a.m.. At noon there was a radio interview with a newsman, which McClure reported was very exhausting. A test scheduled for 12:45 p.m., but not completed, involved McClure attempting to track a missile from launch to impact with the target at 80,000 feet. This was to be the first downward view of a missile firing. Unfortunately, the missile launch was cancelled at 1 p.m.. [125]

About this time, the Command Post personnel discovered that McClure's voice revealed signs of deteriorated performance. He reported that he felt warm, and his pulse rate and temperature had increased. Capsule temperature was still within normal limits, causing concern. It was discovered that McClure had not consumed any liquid for the past 11 hours. McClure was directed to consume water, but he discovered the tube to his drinking water supply would not function properly, and he was able to

get only a few drops of water at a time. After working on the system for about 10 minutes, he discovered a method to correct the problem and began his liquid intake. [126]

Capsule temperature at head level had climbed to 96 degrees and McClure's internal temperature was also still climbing. At about 2 p.m., the Command Post personnel decided to end the mission and ordered McClure to valve off gas and descend. One hour later it was determined the balloon had descended only a few thousand feet and a consistent and reliable descent rate had not been established. McClure's internal temperature had now reached 104.1 degrees. [127]

By 4 p.m., the balloon had established a descent rate of approximately 500 feet per minute and was passing through the 87,000 feet mark. After another hour, McClure's internal temperature had gone up another degree, but the capsule temperature had increased only one degree. The Command Post expressed concern that McClure would become unconscious. Had that occurred, the Command Post could have initiated separation and deployment of the parachute, but that would have resulted in a hard landing with possible injury to McClure. [128]

Communications with McClure were permanently interrupted when he dropped his spot photometer on the floor. The instrument jammed the foot switch of the capsule transmitter so he could receive but not transmit. The Command Post finally determined that McClure was still conscious when the flashing marker beacon on the capsule illuminated while the balloon had descended to 25,000 feet. At 6:42 p.m., the capsule landed in the dark within a few miles of the runway from which it had been launched. A recovery helicopter landed beside the capsule in time to see McClure crawl out under his own power. [129]

After the flight, it was determined that McClure's final internal temperature reading was 108.5 degrees. An hour later, in the base hospital, his EKG showed no abnormality and his pulse rate and internal temperature had dropped. He was alert, but tired. After intravenous fluids and a night's rest, McClure seemed to be his usual alert, bright, and cheerful self. [130]

Manhigh III was the third and last flight of the Manhigh project. These flights into the stratosphere were a major contribution by the Air Force Aeromedical Field Laboratory in the area of human performance and a major test of the reliability of sealed systems under space-equivalent conditions.

SUMMARY AND CONCLUSIONS

Early Cold War missile and rocket testing was conducted at Alamogordo Army Air Field/Holloman AFB because it was the ideal location for such tests. The base was fairly isolated, there was an abundance of uninhabited land and military-controlled air space, and the climate was mild. As a result of these conditions, HAFB became the prime test center when the Army Air Corps consolidated all missile and rocket programs in 1947. In support of these programs, numerous instrumentation sites were created, and aeromedical research was carried out. The data collected from this research was applicable to national defense and instrumental to the 'Man in Space' program.

Blockhouses and photo towers, firing aprons, concrete pads, and a variety of associated debris scattered throughout the base remain as evidence of some of the United States' earliest missile and rocket programs such as the GAPA, NATIV, JB-2, and Aerobee. Most of these programs and their associated physical remains had never been investigated. Many of the programs were still unknown to the general public because of the secrecy surrounding their initial use.

The investigation of these early programs and archaeological documentation of the abandoned facilities has provided the answers to many of the research questions initiated at the beginning of this project. There is now a better understanding of the types of programs conducted on the base, which, in turn, has assisted in the identification of the numerous physical remains scattered throughout the area.

This report focuses strictly on HAFB, even though there was overlap between the programs carried out on the base and on WSMR, particularly when the two installations were part of the same integrated range. A synthesis of data from WSMR with the results provided here would provide a much better overview of the early military test programs carried out in the Tularosa Basin. It should be noted that, at HAFB, many other types of missiles and rockets were tested, a variety of instrumentation sites were used in their support, and additional aeromedical research was conducted. The programs discussed here are only a small part of HAFB's research contributions which began in the late 1940s and continue today.

Since many of the research questions overlap, they are not discussed separately. The discussion is focused instead on the temporal progression of early programs on HAFB and the types of testing conducted at particular launch complexes. Programs and archaeological sites are discussed as they have been identified throughout the report.

The Programs

Most of the early missile and rocket testing conducted at HAFB occurred at two launch complexes. In support of the test programs, instrumentation stations were constructed, and aeromedical research was initiated to supply live subjects for various tests and to study space biology and biodynamics.

The Early Years, 1947-1949

The guided missile research program began on HAFB with the transfer of 1200 personnel from Wendover Field, Utah in March 1947, as part of the USAF's consolidation of missile development. Three ongoing projects included in this transfer were the GAPA, JB-2, and Tarzon (the latter was not investigated during this project). Plans were immediately drawn up for the construction of launch facilities for the GAPA and JB-2, as well as the newly developed NATIV, within what is today known as the Missile Test Stands Area. This area was used extensively from 1947 through the late 1950s (Table 14). With most test programs, the Air Force provided the facilities and contractors used their own vehicles to conduct the tests.

Missile Test Stands Area

In 1947, an observation bunker and firing apron were constructed in the MTSA for launching the first missile from HAFB, a GAPA on 23 July 1947. The Boeing Airplane Company's Ground-to-Air-Pilotless-Aircraft had various configurations to test different propulsion systems, especially ramjet. Seventy-two of these experimental high velocity test vehicles were launched from the MTSA between 1947 and 1950. One GAPA attained an altitude of 59,000 feet, the highest elevation for supersonic ramjet propulsion reached at that time.

In that same year, a second launch complex was constructed to the east of the GAPA facility for the North American Test Instrument Vehicle. Static testing for North American Aviation's NATIV began in January 1948. The NATIV was primarily a research vehicle, but may also have been used for short-range, surface-to-surface and surface-to-air ordnance delivery. [1] Six successful NATIV launches were conducted from a 182 foot high tower before the project ended in November 1948.

The third complex constructed in 1947 included a 440 foot long inclined dirt launch ramp adjacent to the NATIV complex for the JB-2 program. The existing NATIV observation bunker was used for the program. The Army Air Force version of the German V-1 was used to evaluate and advance methods of launching and guidance for this guided missile weapon system. Originally tested at Eglin AFB, Florida, in 1944, the program moved to Wendover Field after the war, and was transferred, along with the rails for the launch ramp, to HAFB in 1947. Although the program had been canceled before the final move, 11 JB-2 launches were completed between May and October 1948.

In 1948, plans for a fourth launch complex were completed to the west of the other three. The Aerobee complex was very similar in configuration as the earlier GAPA and NATIV facilities. The Aerojet Aerobee rocket program was for development of an upper air research vehicle/sounding rocket with a satisfactory parachute recovery system. The Aerobee rocket was used for photographic, solar radiation, biomedical, and atmospheric measurement tests. Early Aerobee testing took place on WSMR in 1947 and 1948. HAFB's first launch of an Aerobee X-8, from a 60 foot tall tower, was in December 1949. The first color motion pictures of the earth's surface were taken during this flight, but the film was lost. Beginning in April 1951, many flights carried monkeys and mice from the Aeromedical Field

Table 14
HAFB Programs, 1947 - 1980

Program	1947	48	49	**1950**	51	52	53	54	55	56	57	58	59	**1960**	61	62	63	64	65	66	67	68	69	**1970**	71	72	73	74	75	76	77	78	79	**1980**	81	82	83	84	85	86	87	88	89	**1990**
MTSA																																												
GAPA	B			E																																								
NATIV	B	E																																										
JB-2	B	E																																										
Aerobee			B										E																															
Matador /Mace		B											E?																															
Falcon			B?						E																																			
Instrumentation																																												
Fixed Cameras	B?							E?																																				
Towers								B																>?																				
High Speed Test Track				B																																								>present
Able 51																																												
Matador													B?											>?																				
Mace													B?											>?																				
BQM-34A																								B?									>?											
Aeromedical Research																																												
Balloon Tests				B			E																																					
Aeromedical Research Lab							B																		E																			
Holloman Zoo													B												E				Albany College							Primate Research Lab								>present
Escape Physiology					B						E																																	
Automotive Crash Tests									B			E																																
Bopper Sled									B			>?																																
Daisy Test Track									B																									E?										
Project Excelsior											B			E																														
Project Manhigh										B		E																																

Program 1947 48 49 1950 51 52 53 54 55 56 57 58 59 1960 61 62 63 64 65 66 67 68 69 1970 71 72 73 74 75 76 77 78 79 1980 81 82 83 84 85 86 87 88 89 1990

B=beginning, E=end, BE?=possible beginning or end date, —>end date unknown

Laboratory. One hundred Aerobee X-8 and Aerobee Hi rockets were launched between 1949 and 1959 when the newer 152 foot tall tower was dismantled and moved to WSMR. The Aerobee Rocket program became the longest continuous rocket program in the United States, spanning 37 years and setting many records in aerospace history.

Two or three additional test programs were apparently conducted from the MTSA, but little is known about the use of these missiles and what physical remains are associated with them. The Martin Aircraft Company constructed the Mace and Matador missiles. The Matador was the first USAF missile to reach operational status. It was a low altitude, high subsonic, surface-to-surface missile. The first Matador launched at HAFB was on December 1948, possibly from the MTSA. The Mace was a long range surface-to-surface missile capable of carrying a large nuclear warhead. It was first tested at HAFB in the late 1950s. Both missiles could be fired from fixed or mobile launchers. Official records from January 1950 list a Martin Fire Control facility in the vicinity of the Aerobee launch complex, which can be seen in the background of an early Mace launch photograph (see Figure 29). It is possible that a number of the unidentified features north of the Aerobee complex represent a fifth complex for Mace and/or Matador mobile launches, which continued at Able 51 in 1959.

The Hughes Aircraft Company Falcon missile was apparently launched from within the JB-2/NATIV complex. The Falcon was the world's first operational guided air-to-air missile. The first HAFB launch was in March 1949, perhaps from the wing of a tied-down B-25 aircraft beside the JB-2 ramp. The modifications to the JB-2 ramp and a number of unidentified features at the north end of the ramp have tentatively been associated with use of the Falcon. A cable trench from the NATIV blockhouse to these modifications also suggests use of this observation shelter for the tests. The Rocket Motor Conditioning Building (Building 1127), constructed in 1954 within the JB-2/NATIV complex, may also have been for the Falcon program and suggests that Falcons were tested up until at least the mid-1950s.

To record data on the numerous missile and rocket tests conducted from the MTSA, a variety of instrumentation stations were constructed. Negotiations had also started for construction of the High Speed Test Track for the Snark intercontinental missile program.

Instrumentation Sites - Cinetheodolite Stations

With the initiation of missile testing on HAFB in 1947, a series of instrumentation stations for recording data from the test programs, including cinetheodolite fixed camera ground stations, were constructed. These stations were used during tests from the MTSA, and possibly for later work from Able 51.

Two cinetheodolite fixed camera stations are in the MTSA, and a third is 2-1/2 miles to the northeast. German Askania cinetheodolite cameras were used at these stations to visually track ground-to-air test objects during their flight to obtain information regarding azimuth, elevation, altitude, range, attitude, and position of control surfaces. Many 'Peter' stations are known to have been on HAFB, but only these three had been documented at the time of the project. Land-Air, Inc., operated the facilities

after January 1949. Prior to that, these facilities were operated by HAFB enlisted men and personnel from North American Aviation, Boeing Airplane Company, Glenn L. Martin Company, and Hughes Aircraft Company. It is unknown exactly when the cinetheodolite stations were established or when they were abandoned, but it is likely they were associated with the first missile launches in 1947 and 1948 and were operated until at least the establishment of Missile Theodolite towers in 1954.

Aeromedical Research

HAFB's first role in aeromedical research consisted of support services for V-2 launches at White Sands Missile Range between 1946 and 1950. This testing consisted of sending fungus spores, monkeys, and mice in V-2s to expose them to cosmic radiation. These tests were not successful.

Further Advances, 1950-1969

Missile testing continued at the MTSA with the Aerobee, Matador/Mace, and Falcon into the late 1950s (see Table 14). As the MTSA fell into disuse, a new facility was constructed and different types of tests were conducted. The fixed camera ground stations continued to be used into the mid-1950s until they were replaced with better facilities. Aeromedical research also continued, with programs going beyond the support of missile testing.

Able 51

The Zero Length (ZEL) facility at Able 51 is a typical example of the United States early Cold War defense posture. The facility was constructed in 1959 as an experimental building to protect a fighter plane during an atomic blast and to launch the plane into the air if the runways were disabled. The ZEL launcher was similar to the Navy catapults used on aircraft carriers. The first launch using the ZEL launcher was in 1959, using a manned F-100 aircraft with a booster rocket motor. More extensive testing in that year was conducted with the Mace and Matador missiles, which are described above.

Fixed and mobile launchers were used during tests. The fixed launchers were inside the ZEL building, while mobile launchers could be secured on concrete aprons outside the ZEL building, or to the north on the Matador firing apron. The exact date of Matador testing at Able 51 is unknown, because the program began in 1948 with launches from other locations.

In 1960, a new guided missile blockhouse (Building 1440) and mobile launch pads were constructed. Sometime in the late 1960s or early 1970s, Mace and Matador testing ceased at HAFB, and Able 51 became the launch point for the BQM-34A 'Firebee' target drone, constructed by the Teledyne-Ryan Company. This testing continued into the late 1970s, when the drone function at HAFB was abolished and the use of Able 51 was discontinued.

High Speed Test Track/Horizontal Test Stand

The initial 3,550 foot long HSTT and a control blockhouse were constructed in 1950 for testing the Snark missile. A variety of programs were conducted on the track, including drone testing, flight control and guidance system research, aerodynamic tests, ejection seat research, and speed tests. The latter included Lt. Col. John Stapp's famous Mach 0.9 sled ride. The track was extended by 1,521 feet in 1952, and to its current length of 35,000 feet in 1957. As part of the this extension, numerous support buildings were constructed, including the Horizontal Test Stand. The HTS was placed on HAFB because of Cold War tactics requiring future missile development and testing be conducted away from seacoasts for defensive reasons. The HTS was intended for Atlas Intercontinental Ballistic missile engine tests, but was apparently never used for that purpose. Instead, the facility was utilized for servicing liquid-fuel sled engines for the HSTT until the mid-1970s.

Instrumentation Sites - Missile Theodolite Towers

Fixed camera ground stations continued to record data on missile and rocket testing from the MTSA until at least the mid-1950s. In 1954, a series of Missile Theodolite towers were constructed to provide more protection for the Askania cinetheodolite cameras, and these were operated in the same manner as the ground stations. The cameras were mounted on a pedestal on the third floor of the tower, protected by retractable roof panels which slid down during use. The towers were probably used until the testing at the MTSA was discontinued in the late 1950s, but may have continued in use for Able 51 test flights into the late 1970s.

Aeromedical Research

Aeromedical operations were transferred from WSMR to HAFB in 1950. Initial studies used balloons to transport equipment and test animals to high altitudes. Monkeys and mice were sent up in Aerobee rockets between 1951 and 1952. This upper atmospheric research was designed to study the biological affects of cosmic radiation and weightlessness, and altitudes of 36 miles were successfully achieved with the rockets. Altitudes of up to 100,000 feet were achieved with balloons before launches were transferred to other locations in 1953.

In that same year, the Aeromedical Field Laboratory, created in 1951 to support Wright Field, Ohio, programs, was assigned to HAFB. The AFL housed the Holloman Zoo, which provided test animals for biomedical research and also conducted research into the biophysics of abrupt deceleration. The Zoo housed mice, hamsters, dogs, and cats, and was the only Air Force agency to have chimpanzees, hogs, and bears. The Zoo was part of the Aeromedical Research Laboratory from 1959 through 1971. Two of the most famous residents of the Zoo were HAM and Enos, the first 'chimpnauts,' who in 1961 preceded the Mercury astronauts into space.

Subgravity tests were conducted in 1957 using F-94C aircraft. These tests subjected humans to forces of up to 4 to 5 Gs. Cats were also included in the tests because of their renowned balance. Later

experiments used more advanced aircraft such as the F-100, F-104, C-131, and KC-135. The Mercury astronauts were tested in the C-131.

The HSTT was used in some aeromedical research between 1951 and 1957. Tests in escape physiology, including the effects of ejection force, windblast, and wind-drag deceleration, were evaluated using sleds to simulate pilot ejection from high speed aircraft. In 1951, the possibility of remaining in an ejection seat after bailout was tested using balloons. Subjects rode the seat up, then descended in the seat. Between 1953 and 1957, chimpanzees and humans made sled runs to evaluate windblast and the jettisoning of a canopy. Dr. Stapp made 28 runs, attaining a maximum speed of 937 feet per second. A tumbling seat experiment was conducted to evaluate the combination of tumbling, windblast, and deceleration. Some tests had the seat facing backwards. In 1957, during HSTT modifications, the tests were transferred to China Lake, California. Escape from high-speed aircraft was evaluated in 1955 supported by chimpanzees from the ARL. Chimps were ejected from specially designed missiles at supersonic speed. Investigation of forced landings were also tested using sleds on the HSTT. In 1955, the ARL had a F-102 seat dropped from a sled using dummies and chimpanzees.

The ARL was heavily engaged in automotive crash force investigations. Between 1955 and 1958, dummies and test animals were strapped into vehicles which were crashed into barriers. Energy absorbing steering wheels and bumpers were tested to determine reduction in crash forces. The Bopper Sled was developed by Northrop in 1955 for deceleration tests. Human subjects in the sled were subjected to 12-27 G stops to test seat belts and the affects of deceleration. Another deceleration device was the Swing Seat, which was used for testing energy absorbing steering wheels and seat belts.

The Daisy Test Track was first used in 1955. Sleds were used on the 240 foot long track to test deceleration. An airgun accelerated the sled down the track, which was housed in the ARL compound. A variety of braking devices, ejection seats, and car air bags were tested with dummies, human, and animal test subjects. Sleds were also developed to simulate Apollo space capsule crew couches. Forces of up to 83 G were sustained. The Daisy Test Track was used up until at least 1980s, when it was dismantled.

Between 1957 and 1960, the ARL was involved in Project Excelsior, which was designed to test parachutes and pressure suits for stabilizing the fall of a pilot bailing out of an aircraft at high altitudes. C-130s and balloons took pilots up to 102,000 feet for bailout, also testing their ability to perform under high stress, emergency conditions.

A final test utilizing balloons was Project Manhigh, investigating the affects of space flight on humans and discovering design principles for space capsules. Between 1956 and 1958, both unmanned and manned balloons were sent to heights of up to 126,000 feet.

End of An Era, 1970-present

HAFB became part of the Tactical Air Command (TAC) in 1971, and the base mission went from that of missile testing to training fighter pilots. Missile and rocket testing was winding down at that

point, although testing did continue on the adjacent White Sands Missile Range. Use of the High Speed Test Track continued, and sleds still run the track testing aircraft aerodynamics and ejection seats, and setting new speed records (they have reached Mach 8.6).

The Air Force managed the Aeromedical Research Laboratory until 1971, when the operation became part of the Albany Medical College. In 1980, the Zoo became known as the Primate Research Facility and was transferred to New Mexico State University's Primate Research Institute. Today, the facility is under management of The Coulston Foundation, and the descendants of the early Holloman Zoo chimpanzees are still there.

The Stealth fighter has taken the place of missiles and rockets on HAFB, and the instrument stations are abandoned. The remains of the launch complexes and photo facilities are now archaeological sites and historic buildings, bearing testimony to the early Cold War era at HAFB.

Archaeological Sites

All archaeological sites documented or evaluated for this project were missile and rocket launch complexes or cinetheodolite stations. Research focused on identifying the functions of each site and the association of particular features with the various programs carried out within the facilities. In the case of cinetheodolite sites, this was very straight forward, since these sites were normally single component with a specific function. The two launch sites, The Missile Test Stands Area and Able 51, proved much more challenging since these locales had been used for a variety of different test programs through time. When possible, the sites were compared to similar sites on other installations. Unfortunately, very little comparable information was available.

One discovery which proved invaluable in the identification of launch sites and features was the result of early military efficiency. Rarely during research of historic cultural resource sites is an Archaeologist fortunate enough to find a feature or artifact with the site's name and manufacturer on it. Thanks to the military habit of naming and marking their facilities, the HAFB sites have such a feature. Brass caps bearing the name of programs or contractors were located at the NATIV, GAPA, Aerobee, and Matador complexes (Figure 92). Brass caps with facility names or designations and facility names spelled out in stone graced the individual cinetheodolite stations, with the exception of the two features within the MTSA. The location of these brass

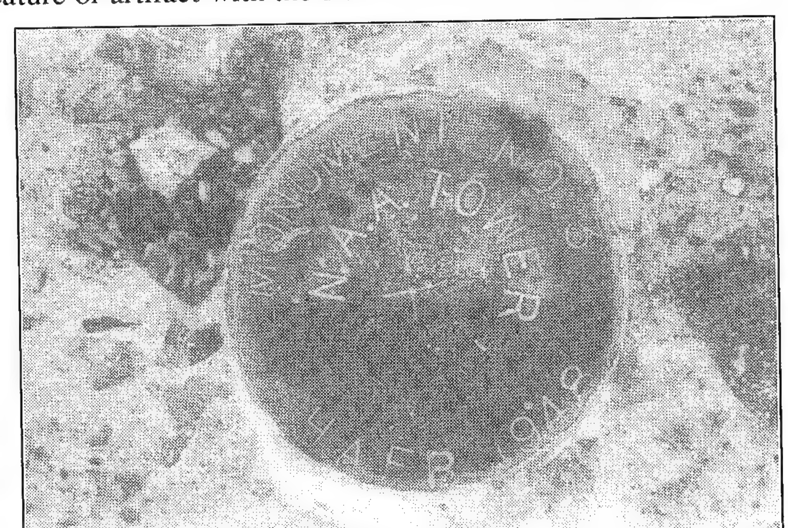


Figure 92. The North American Aviation brass cap on the NATIV firing apron (Allred/Space Center 1994).

caps and rock-aligned names provided the name of the complex, which was necessary when trying to locate archival data. It has also illustrated a special type of feature to search for after locating an unidentifiable military site or feature.

Missile Test Stands Area

The launch facilities for the GAPA, NATIV, JB-2, and Aerobee programs were easily identified by the brass caps mentioned above, which were located on the firing aprons, and by using historic photographs and engineering drawings of the facilities. The brass caps were inscribed with the name of the contractor conducting the testing and the date of installation, which could be corresponded to the individual program. The GAPA, NATIV, and Aerobee complexes were all similar. Each had a concrete observation shelter/blockhouse with cable trenches running to 100 foot square firing aprons. After documentation of the MTSA, it was also noted that each blockhouse had an associated generator house and substation, as well as fire plugs/deluge systems. The metal launch towers and interior furnishings of the blockhouses are no longer present.

There were also differences in the complexes. The blockhouses varied in size and layout. The GAPA complex had an unidentified feature, thought to be a powder magazine, connected to the firing apron with a cable trench, and the NATIV complex had a static test stand connected to the cable run. The bases of two missiles were found imbedded in the ground between the Aerobee and GAPA complexes. One was identified as the booster of an Aerobee, and the second was unidentified. Because the remains are in good shape, it is unclear if these missiles crashed or represent discarded parts.

The JB-2 complex was also very unique. Since the NATIV blockhouse was used for this program, only the dirt ramp and a reinforced concrete box were associated with the facility. Most of the rails on the ramp are no longer present. Many of the features at the north end of the ramp, modifications to the loading pit and ramp, and the Rocket Motor Conditioning Building (Building 1116) apparently were associated with the later Falcon program. This missile was probably controlled from the NATIV blockhouse, because a cable trench connects the modifications to the building. Further research into that program would undoubtedly identify this separate launch complex between the NATIV and JB-2 facilities.

A sixth launch complex which may have been situated in the MTSA is north of the Aerobee complex. A large concrete structure (Feature 117) and a number of concrete pads have tentatively been associated with the early Mace/Matador programs. One of the features (Feature 119) appears to have been a static pad used to secure a mobile launcher for firing the vehicle (see Figure 32).

Comparative data on launch facilities from other installations was limited. Archaeological work has been completed on JB-2 sites at Eglin AFB, which were used between 1944 and 1946. [2] Although used for the same program, the HAFB JB-2 launch ramp was very different than those used on Eglin AFB. One Eglin ramp consisted of concrete pylons which once supported a metal superstructure for a 400 foot long ramp. Historic photos indicated the rails were situated on the freestanding superstructure

and not on a dirt ramp. The second launch facility apparently had two concrete pads for portable, 50 foot long launchers. Both facilities had identical concrete blockhouses. The small, flat-roofed bunkers bear no resemblance to the HAFB observation shelters, which have peaked roofs. There was also numerous JB-2 wrecks on the Eglin sites. At HAFB, with later use of the ramp, such wreckage would probably have been cleaned up if it existed. With the small number of launches at HAFB, it is possible no JB-2s crashed in the vicinity of the ramp. Wreckage, which has not yet been identified, may also be present far from the ramp.

An early GAPA launch site, currently administered by the Bureau of Land Management in Utah, was nominated to the National Register of Historic Places in 1980.[3] This facility was used on Wendover Field between June 1946 and July 1947, when the program transferred to HAFB. The site consists of a 40 foot square, reinforced concrete, semi-subterranean blockhouse, and a 100 foot square concrete firing apron. The blockhouse is unlike those at HAFB, with a flat roof and dirt berms on each side. The inset, trapezoidal-shaped viewing windows, though, are very similar to those in the GAPA blockhouse on HAFB. The firing apron, 300 feet south of the blockhouse and once supporting a 40 foot tall steel launch tower, has the same dimensions as all of the firing aprons on the MTSA. The internal features, consisting of steel rebar and concrete footings, is unlike the tower support features at HAFB.

Apparently, there are dirt JB-2 ramps and other early missile and rocket complexes from Wendover's early testing, which are currently administered by Hill AFB. Unfortunately, these remains have not yet been documented. Debbie Hall, Hill AFB Cultural Resource Manager, indicated the complexes and features are part of a research project now in progress.[4]

All of the HAFB complexes had numerous features around them which could not be associated to a particular program. Unfortunately, the limited data from other installations did not help in the identification process. Aerobee missiles were launched from White Sands Missile Range, but research has not been accomplished on the sites. The GAPA and NATIV programs were transferred from Wendover Field, but the majority of these complexes are also undocumented. Unlike buildings such as aircraft hangers and barracks, which were built to the same Air Force specifications throughout the country, the missile and rocket facilities appear to be unique. The continued use of the complexes for a variety of programs also makes feature association difficult. Even with the original engineering drawings of the complexes, only the prominent structural features are illustrated, leaving the smaller features unidentified. The recent location of a possible aerial photo view of the MTSA on microfilm may help solve some identification problems.

Able 51

As with the MTSA, the Able 51 complex was used for at least three different programs. Fortunately, this site had very few structural features, and these have been identified to specific programs. Of course, many of the features may have been reused at a later date. The ZEL site (Building 1442) was used to launch F-100s and Mace missiles. The Matador firing apron and concrete pads beside Building

1440 were used to support mobile launchers for Matadors and the BQM-34A drone. The original semi-subterranean observation shelter for the ZEL site is no longer present. Apparently, a second blockhouse was present near the Matador pad, but no evidence remains of that feature. Buried cable trenches from this Building 1440 run towards the ZEL site and Matador pad, indicating it may have served as the control center for later tests from those features. This blockhouse is very similar to those documented at Eglin AFB and Hill AFB. All internal features, such as instrument panels and launchers, have been removed from the buildings.

The function of what may be a fourth launch pad (Feature 1) has not been positively identified, although it may have been an early Matador/Mace facility. A plan view map of the Able 51 area shows a number of additional launch facilities, and future research will hopefully help identify them. No comparative data was located indicating ZEL facilities existed on other bases. The site, especially the ZEL building, is a unique example of a Cold War era facility.

Cinetheodolite Stations

Four of the six documented cinetheodolite stations were identified because of brass caps or rock-aligned facility names. The two fixed camera ground stations within the MTSA were not identified by name. The lack of identifiable features at these stations may be a result of the continued use of the area for later programs. It is also possible these features never existed since the facilities were within a larger complex and not an isolated station as with the Bern site. Another series of features common to all but the MTSA features were the target array around the station. The eight targets, with the station in the center, are another feature type which can be used to locate additional facilities (see Figures 55 & 56). Numerous target poles are scattered throughout HAFB and there was, unquestionably, an instrument station in the center of these arrays.

Site documentation and archival research indicated the fixed camera ground stations consisted of a utility building and camera stand connected by a 'sidewalk' with metal rails, a temporary open generator shelter, and a latrine. With the exception of the latrine, which was present only on the Bern site, the three ground stations have the remains of the primary structure and concrete footings for the generator shelter. No superstructures remained. The Bern site, which is a single component site, still has an intact outhouse, a rock-aligned facility name, and a trash pile. A 'temporary cinetheodolite' ground station identified at the Sole site, which predated the Missile Theodolite tower, consisted only of a single pad with a camera stand. Without the characteristic two-pad layout and generator shed foundations, it would be difficult to positively identify this feature as a cinetheodolite station without supporting documentation. Single pads with camera stands are common features throughout HAFB, and further research will be necessary to identify them as cinetheodolite stations or as a different type of instrument facility.

The three Missile Theodolite tower sites have both similarities and differences. The three towers are all identical in construction, and all have (or had) propane tanks adjacent to them, rock-aligned

facility names, latrines, and target arrays. All interior furnishings and air coolers, once in front of the towers, have been removed. The Pritch site had a temporary generator shelter identical to the one pictured for the Bern site, and the Sole site had an un-sheltered generator. The Mart site had a power line running to it. The Pritch site is the only single component Missile Theodolite tower facility, and it is the best example of that site type on the base. The Sole and Mart sites have a number of additional concrete pads and features. A temporary cinetheodolite station was on the Sole site before the tower was constructed, and the unidentified foundation at the Mart site may be a similar instrument station. The Sole site also has many features not identified during the research. It seems apparent the site was used for similar, or completely unrelated functions, after its use as a photo tower ceased.

A number of Missile Theodolite towers are present on White Sands Missile Range. They are identical to those on HAFB. Fixed camera ground stations are probably also present on WSMR, but there was no information available on these types of features.

Historic Buildings

The standing structures within the archaeological sites, as well as the Horizontal Test Stand, were assessed architecturally for a separate project. [5] The buildings included the three observation shelters (buildings 1116, 1139, and 1142) and the Rocket Motor Conditioning Building (Building 1127) at the MTSA, the ZEL building and observation shelter at Able 51 (buildings 1440 and 1442), and the Horizontal Test Stand (buildings 1159 and 1160).

Conclusions

Missile and rocket are no longer tested at the MTSA and Able 51 on HAFB, the cinetheodolite stations have been abandoned, and aeromedical research has been replaced by other types of primate research. Only the High Speed Test Track remains operational, conducting aerodynamic tests as it did almost 50 years ago. The physical remains of concrete blockhouses and photo towers, concrete launch and photo pads, a dirt launch ramp, and a metal launch building still remain, though, to bear testimony to the Legacy of some of the United States earliest national defense and space-related research, and to the contribution HAFB made in the quest for the stars. The Department of Defense has recognized the importance of this early evidence of Air Force heritage, when it could be said, "We Develop Missiles, Not Air!"

RECOMMENDATIONS

National Register Eligibility

The six archaeological sites discussed in this report are all considered potentially eligible for inclusion to the National Register of Historic Places (Table 15). Four sites are considered eligible under criteria A, C, and D, one site under criteria A and C, and one site under Criterion A.

Table 15
National Register Eligibility

Site Name (number)	Criterion	Research Potential
Missile Test Stands Area (HAR-041/LA 104274)	A,C,D	Yes
Able 51 (HAR-039/LA 107799)	A,C,D	Yes
Mart site (HAR-018r/LA 107798)	A,C,D	Yes
Pritch site (HAR-007/LA 99633)	A,C	No
Sole site (HAR-005/LA 99457)	A,C,D	Yes
Bern site (HAR-021/LA 102577)	A	No

All of the sites are eligible under Criterion A because of their association with early, post-WWII rocket and missile development in the United States, and the role which HAFB played in early space technology. The sites "possess exceptional value or quality in illustrating Cold War heritage in the United States, . . . possess a high degree of integrity of location, design, setting, materials, workmanship, feeling, and association," and "are directly associated with events that have made a significant contribution to . . . the broad pattern of United States Cold War history and from which an understanding and appreciation of those patterns may be gained . . .." [1] Able 51 and the MTSA are especially

interesting because they contain the remains of a variety of different types of missile, rocket, and drone launch facilities within their boundaries.

The three Missile Theodolite towers and two launch facilities are also eligible under Criterion C. Each site has intact structures which are architecturally unique and "embody the distinguishing characteristics of an architectural, engineering, technological, or scientific type specimen exceptionally valuable for a study of a period, style, method, or technique of construction . . .." [2] The Missile Theodolite towers represent an atypical, German-designed, concrete observation tower unique to HAFB and WSMR. The observation blockhouses in the MTSA are also unique, constructed unlike representative examples from other bases. The observation shelter on Able 51 represents a more typical Cold War concrete blockhouse-style construction. Building 1442 on Able 51 is a very atypical temporary-style, atomic blast-proof metal launch facility. The significance of these buildings is discussed more in-depth in a soon-to-be completed architectural assessment. [3]

Finally, the two launch facilities and two of the Missile Theodolite towers (Sole and Mart sites) also fit under Criterion D for their potential to yield further information important to the understanding of early United States' missile, rocket, and drone testing. A variety of test programs were carried out at the two launch sites, and many of the features documented at the sites remain unidentified. The Sole and Mart sites also have unidentified features which may represent other instrumentation programs. The identification of these features may add information on the various testing programs to which they were associated.

The Bern site (HAR-021/LA 102577) deserves special mention. After its original documentation, the site was determined not to be eligible because "it was not 50 years old, unique to HAFB or other bases in New Mexico, or distinctive enough to warrant consideration as contributing to the nation's cultural heritage." [4] Although the remains of this facility do not have architectural integrity and the physical remains cannot add further information to our knowledge of cinetheodolite stations, current research indicates the uniqueness of this type of instrumentation station and its role in early missile development on HAFB. The Bern site is the best documented example of a cinetheodolite fixed camera ground station on HAFB, and no other sites of this type are known in New Mexico or on USAF installations elsewhere in the country. For these reasons, the site has been considered potentially eligible for the National Register.

Management Considerations

The location of archaeological sites in the unimproved areas of a military installation has kept disturbance and vandalism to a minimum because of limited access. The sturdy construction of the remaining blockhouses and concrete pads has also reduced the extent of natural weathering factors. With the exception of the Mart site, all sites are at a distance from HAFB's main cantonment area, thus reducing military use of the facilities. At the same time, the remoteness of the sites is responsible for

the vandalism which has occurred because they are beyond the routine patrol routes of base Security Police.

All of the sites have evidence of past military maneuvers. Spent M-16 and M-60 cartridges, cartridge belt links, and discarded military equipment are present, and vehicle tracks cross most sites. The Sole site has been used as a defensive area during more recent maneuvers, but this practice has ceased. These maneuvers did little damage to the sites and their features other than leaving future artifacts behind.

Vandalism has occurred at five sites. The Sole site and Able 51 have had the most extensive damage. On the Sole site Missile Theodolite tower, the front door, aluminum roof, and interior walls and stairway are full of bullet holes. Graffiti is painted on the tower and many of the associated features. Numerous padlocks have been broken off the front door. The current curator of the building, the Defense Mapping Agency, has blocked the windows with concrete and braced the door with iron straps to prevent illegal entry. Building 1442 and Feature 13 at Able 51 have had extensive graffiti painted on them. Disturbance at the remaining sites has been minimal. The Pritch site Missile Theodolite tower has broken windows. At the MTSA, graffiti is painted on the Aerobee blockhouse, bullet holes are in all the blockhouse windows and the metal shed on the Aerobee firing apron, and recent trash dumping has occurred in the JB-2 loading pit. The Bern site outhouse has been pushed over.

Although it is difficult to prevent further vandalism, a number of methods are being undertaken. A "DO NOT DISTURB" sign has been installed at the Sole site, and vandalism appears to have dropped off. [5] All sites are periodically visited by the Base Archaeologist. Public education of base civilian and military personnel, through the base newspaper and letters to various military organizations involved in training exercises, has increased awareness of the significance of the sites and reduced disturbance significantly. Additional warning signs will be installed at all sites, and periodical monitoring shall be continued.

Currently, the blockhouses at the MTSA are used by various base organizations for storage purposes, and the Horizontal Test Stand is still used by High Speed Test Track personnel. Building 1440 at Able 51 was recently acquired by the Base Archaeologist for a curatorial facility. This nondestructive reuse of the buildings shall continue to be emphasized because it creates a use for the facility without a need for modification while preserving the buildings integrity.

Project Analysis

The Early Missile, Rocket, Instrumentation, and Aeromedical Research Development project was conducted in two phases. The first consisted of documenting known archaeological sites and associating features with test programs. The second included archival research on the test programs performed at the sites, and programs not associated with physical remains. This work can only be considered the initial step in documenting a select number of the various test programs carried out on HAFB in the

early Cold War. The most recognized programs and previously known archaeological remains have been documented and researched. The research uncovered additional test programs which were previously unknown, and many informants who participated in the programs investigated have came forward. With few exceptions, numerous features on the sites remain unidentified, and more sites associated with the programs, especially instrument facilities, have yet to be relocated. An analysis of this project might help other installations conduct similar studies more efficiently, and to avoid the pitfalls encountered here.

Early into the research process, the immensity of the test programs and amount of data available was discovered, making it impossible to do more than 'scratch the surface' on the history of the early HAFB programs. In some cases, the amount of data was determined to be so large, such as with the High Speed Test Track, that it could not be handled within the scope of the original project. It was determined that most of individual programs and archaeological sites should be investigated as separate projects, so research could be more focused.

The most time consuming part of the project was locating early military records pertaining to programs and facilities. Most Air Force base histories focus on Squadrons and Fighter Wings, which change through time. As units move, they take their records with them. Fortunately, many of these records have been put on microfilm or stored in central museums or libraries. When initiating research, a query of a few organizations should be conducted to determine how much information is available on a particular installation or program. If combining research with archaeological sites, conducting the research first will eliminate the need to return for more data after new features are located.

1. *Maxwell AFB*. Lists of records can be obtained by querying the installation name, such as 'Holloman,' or a particular program, such as 'Aerobee.' Using the Holloman query, over 300 pages of indexed records were recovered. These records listed call numbers, inclusive dates, security clearance, title, format (i.e. hard copy, microfilm, etc.), author, and a brief abstract of the document. After reviewing the list, the documents can be ordered. Many rolls of microfilm, which were imperative to the research, were obtained and contain information not available elsewhere.

2. *National Archives*. The National Archives also has information on installations, which can be queried by name or program. A visit to this organization can uncover data not available at Maxwell AFB. The Directorate of Real Estate can provide information concerning current or former Army or Air Force reservation files.

3. *The Installation*. At HAFB, for example, original facility construction blueprints were located in the Civil Engineering drawing vault. These drawings provided valuable information on construction dates, site layouts, and feature identifications. The Real Property office has records on all existing facilities, which is helpful if there is extant architecture. Organizations still in operation, such as the

High Speed Test Track, may also retain historic documents and have a library. The base library often has a reference section and may have copies of early base newspapers and yearbooks.

4. *Local Libraries.* Local city and university libraries have a wide array of information. City newspapers dating back to the early days of a base generally reported on unclassified programs and interesting happenings on an installation. Base visitors' guides and yearbooks can also be located. University libraries may have theses or dissertations focused on base activities, or general subject matter on research and testing programs.

5. *Other Installations.* In the case of HAFB, which conducted joint projects with White Sands Missile Range, many records pertaining to the base were located in range files. Comparative material was also located at Eglin AFB and Hill AFB, where similar test programs were conducted.

6. *Retired Individuals.* Many base personnel retire near an installation where they worked. These people can provide a wealth of information, and often have photos and documents from their work on test programs. Locating such individuals can be accomplished with articles in base or local newspapers asking for information.

It is also important to determine military designations of facilities or programs, since data is often archived under that designation. This is not always an easy task since the names and numbers often changed through time. For instance, one cinetheodolite station on HAFB appears to have been known as the 'Sole site,' 'Boeing 19,' 'George 58,' and 'Peter 8,' and the Missile Theodolite tower on the site had separate Air Force and Army building numbers. Locating military brass caps at the site helped begin the process of identification. Records for the facility were located at HAFB under the building number, at WSMR under the site name, and in various archives under the site function (instrumentation sites).

The archival research should be conducted before the physical remains of the facilities are documented. This will allow for the use of historic documents and photos for locating and identifying features and eliminate the need for numerous trips to a site. Finally, when documenting archaeological sites, it is always useful to use English measurements for features rather than the metric system normally used by archaeologists. Since historic records and building blueprints use the English system, this makes the identification of features from the records much easier.

Future Research

Future research is necessary to add to the data collected for each of the programs and sites discussed above, and also to identify additional programs and facilities. A number of research avenues are listed below.

1. *Site Location and Identification.* From a management standpoint, the location and identification of additional archaeological sites is critical. Once these sites are documented, they can be protected from future base undertakings. In the course of this research, historic maps and documents were located which identified a number of facilities, especially instrumentation stations, which have not been documented. Numerous military facilities have also been identified from previous archaeological surveys. The functions of many of these concrete pads and instrument stands have not yet been identified. Use of historic maps and documents may aid in the identification of features and association of the sites with other instrumentation facilities. Once these sites are identified, patterns for strategic placement of the various facilities can be determined, and sites without impressive physical remains might become significant because of their association with early test programs on the base.

2. *Feature Identification within Known Sites.* The launch complexes and two of the cinetheodolite sites have features which have not been associated with specific programs. Further research, including oral interviews, should focus on the identification of these features. New test programs might be discovered, or features might be associated with the known programs. The identification of these features will add to our knowledge of known, and perhaps unknown, test programs and the types of facilities needed to support these programs. One example is the use of the MTSA for Falcon and Mace/Matador testing. More in-depth research of these missile programs might help to identify many of the unidentified features on the site.

3. *Future Research.* One of the more important aspects of the research conducted for this project was identifying the many locations of historic military documents. Since much of this information has been transferred to microfilm, the investigation of this medium was well beyond the scope of the project. Future research should focus on investigating the reams of microfilm and other military documents located in such places as the Maxwell AFB archives and the National Archives in Washington, DC.

Oral interviews are another important aspect of historic research. Many retired military and civilian personnel who once worked on the test programs live in or around Alamogordo. It is imperative that these individuals are interviewed before the information they possess is lost. Videotaping these individuals on the actual sites where they worked is recommended. The International Space Hall of Fame has an active oral interview program, and the current project uncovered a number of new prospects for this program.

Finally, the High Speed Test Track was not investigated because it was determined to be beyond the time and funding restraints of this project. This facility was, and still is, an important part of test programs on HAFB. Future research is planned in order to begin investigating the extensive records available for this important facility.

4. *Synthesis of Data.* The research conducted here focused on the programs and sites located on HAFB, which represent only a small part of the Cold War testing carried out in the Tularosa Basin, and, in a larger sense, the United States. Missile and rocket testing, supported by various instrumentation facilities, was carried out on WSMR and other bases such as Eglin AFB in Florida and Wendover Field in Utah (much of which is now part of Hill AFB). Little emphasis was placed on locating historical or archaeological studies from these installations. Data from other military installations should be synthesized with the data collected on HAFB, to create a 'big picture' of the early missile, rocket, drone, and instrumentation testing, and aeromedical research which were the initial steps leading to the current United States space program.

Interpretive Possibilities

Public education is an important aspect of all cultural resource preservation programs. Very few base personnel are aware of the role of HAFB as a missile development installation. Three of the archaeological sites are ideal for public interpretation. The MTSA, Able 51, and the Mart site are located close to the HAFB cantonment area. Interpretive trails with wayside exhibits and signs could be created, with an interpretive loop drive between the sites. This publication will also provide base personnel with information on the base's early programs and the importance of the archaeological sites still remaining on the base.

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APPENDIX 1

Time Line of
New Mexico's Contribution to Space Exploration

25 July 1930 - Robert B. Goddard, 'Father of Modern Rocketry,' arrived in Roswell, NM.

19 April 1932 - Goddard developed and fired the first gyroscopic-controlled rocket.

6 February 1942 - Start of construction of the Alamogordo Army Air Field, later known as the Alamogordo Bombing Range, and finally as Holloman Air Force Base.

9 July 1945 - Establishment of White Sands Proving Ground.

16 July 1945 - First atomic bomb detonated at Trinity Site.

26 September 1945 - First firing of a rocket (Tiny Tim) at White Sands Proving Ground.

November, 1945 - First contingent of scientists from Germany arrive at White Sands Proving Ground under Project Paperclip.

15 March 1946 - First static test of a V-2 rocket at White Sands Proving Ground. Test lasted 57 seconds.

16 April 1946 - First flight of a V-2 at White Sands Proving Ground.

5 June 1947 - First balloon launched at Holloman Air Force Base. Made of rubber and only seven feet in diameter.

23 July 1947 - First missile, Ground-to-Air Pilotless Aircraft (GAPA) launched from Alamogordo Army Air Field.

24 November 1947 - First launch and flight of an Aerobee rocket at White Sands Proving Ground.

13 January 1948 - Alamogordo Air Force Base renamed Holloman Air Force Base.

20 September 1951 - First successful recovery of a monkey and 11 mice from a Holloman Air Force Base Aerobee rocket flight.

1951 - Aeromedical Field Laboratory organized at Holloman Air Force Base for biological rocket flight research.

1 September 1952 - Consolidation of White Sands Proving Ground and Holloman Air Force Base Ranges. WSPG assigned operational control of the Integrated Range.

19 September 1952 - Last firing of a V-2 at White Sands Proving Grounds.

10 December 1954 - Colonel John P. Stapp, 'The Fastest Man on Earth,' rode the Sonic Wind No. 1 rocket sled and reached a speed of 639 mph in five seconds.

15 October 1955 - First Sodium Vapor Cloud placed in exo-atmosphere by Holloman Air Force Base Aerobee rocket.

16 October 1957 - First man-made objects to escape earth's gravity released from Holloman Air Force Base Aerobee rocket.

1 May 1958 - The name of White Sands Proving Ground officially changed to White Sands Missile Range.

21 June 1959 - Last two Aerobees launched at Holloman Air Force Base.

July 1959 - Astrochimp 'HAM' arrives at Holloman Air Force Base for training for space flight.

1964 - NASA's Johnson Space Center, White Sands Test Facility, was established near Las Cruces, NM, to test propulsion and guidance systems.

5 February 1971 - New Mexico's first Astronaut, Edgar D. Mitchell, landed on the moon in Apollo 14 and set up an automated science laboratory.

April 1972 - Apollo 16 astronauts John W. Young and Charles M. Duke trained near Taos, New Mexico, for their lunar landing.

11 December 1972 - New Mexico astronaut Harrison H. Schmitt, in Apollo 17, landed and walked on the lunar surface.

5 October 1976 - Dedication of the International Space Hall of Fame at Alamogordo, NM.

January 1981 - National Radio Astronomy Observatory, VLA (Very Large Array), near Socorro, NM, became fully operational.

30 March 1982 - Space Shuttle Columbia (STS-3) landed on Runway 17 at Northrop Strip on White Sands Missile Range at 9:05 a.m.

11 May 1982 - Northrop strip renamed White Sands Space Harbor by President Reagan.

January 1985 - The TDRSS (Tracking and Data Relay Satellite System) at White Sands Missile Range became fully operational.

17 January 1985 - Last Aerobee missile launched at White Sands Missile Range.

October 1985 - Launch Complex 33 at White Sands was designated a Historical Landmark by the National Park Service.

ABOUT THE AUTHORS

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